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(54) Air conditioning system and operating method therefor

(57) An air conditioning system formed by connecting at least one indoor unit 10a, 10b, 10c with an outdoor unit 1 by piping, wherein a control apparatus (18) for controlling the system includes:- a discharge temperature control device (27) for controlling the opening angle of an outdoor expansion valve 8 so as to reduce a deviation of a detected value of discharge temperature or degree of discharge superheat of a variable-capacity compressor 2 from a target value; a room temperature control device (32) for controlling a deviation of a detected room temperature from a set room temperature in order to reduce the deviation; and a discharge pressure control device (22) for controlling the number of compressor revolutions so that the compressor discharge pressure reaches a specified value, and an electric-power-minimizing device (34) for computing minimum power consumption searches for a state for reducing a detected value of an electric power detector (33) based on fed-back output quantities of the above-mentioned three devices.

FIG. I

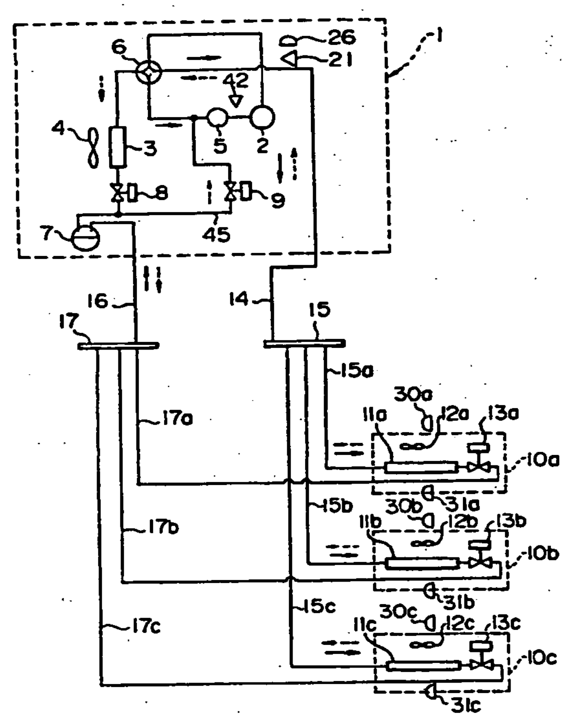

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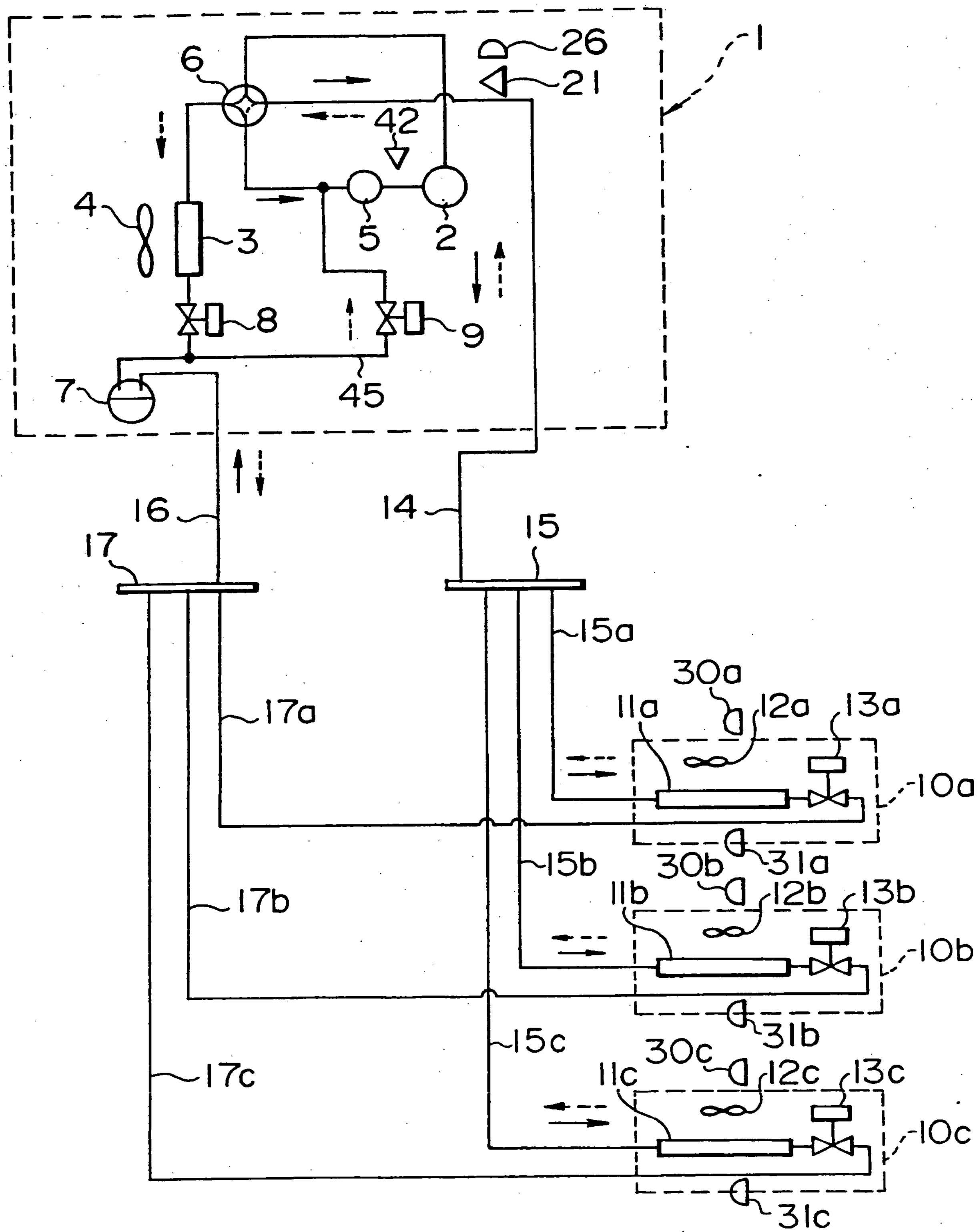
FIG. 1



26
21
6
42
1
4
3
5
2
8
9
7
45
16
14
17
15
15a
30a
17a
11a
12a
13a
10a
31a
15b
30b
17b
11b
12b
13b
10b
31b
15c
30c
17c
11c
12c
13c
10c
31c

FIG. 2

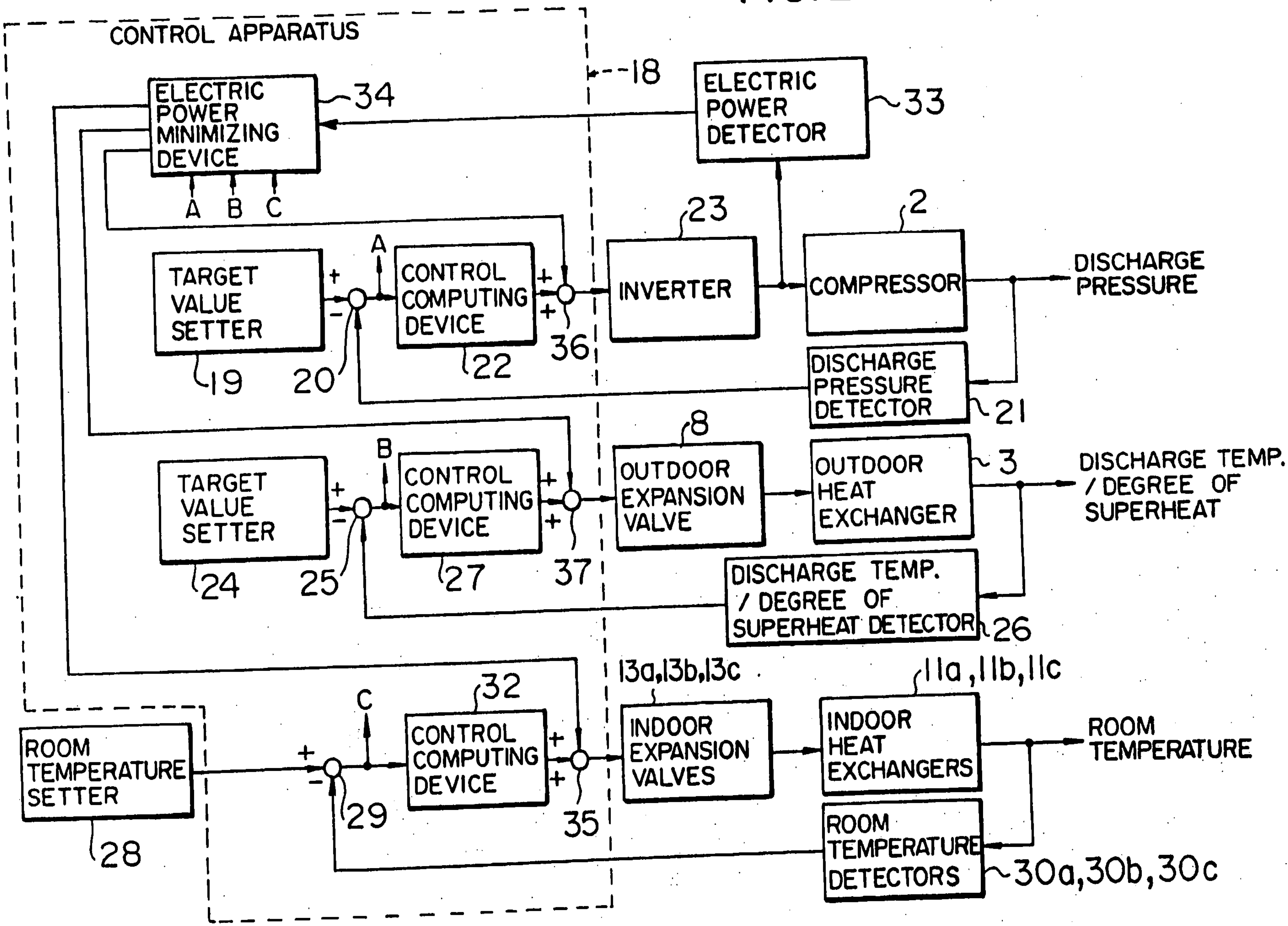

CONTROL APPARATUS
18
ELECTRIC POWER MINIMIZING DEVICE
34
A B C
ELECTRIC POWER DETECTOR
33
TARGET VALUE SETTER
19
20
A
CONTROL COMPUTING DEVICE
22
36
INVERTER
23
COMPRESSOR
2
DISCHARGE PRESSURE
DISCHARGE PRESSURE DETECTOR
21
TARGET VALUE SETTER
24
25
B
CONTROL COMPUTING DEVICE
27
37
OUTDOOR EXPANSION VALVE
8
OUTDOOR HEAT EXCHANGER
3
DISCHARGE TEMP. / DEGREE OF SUPERHEAT
DISCHARGE TEMP. / DEGREE OF SUPERHEAT DETECTOR
26
ROOM TEMPERATURE SETTER
28
29
C
CONTROL COMPUTING DEVICE
32
35
13a,13b,13c
INDOOR EXPANSION VALVES
11a,11b,11c
INDOOR HEAT EXCHANGERS
ROOM TEMPERATURE
ROOM TEMPERATURE DETECTORS
30a,30b,30c

FIG.3

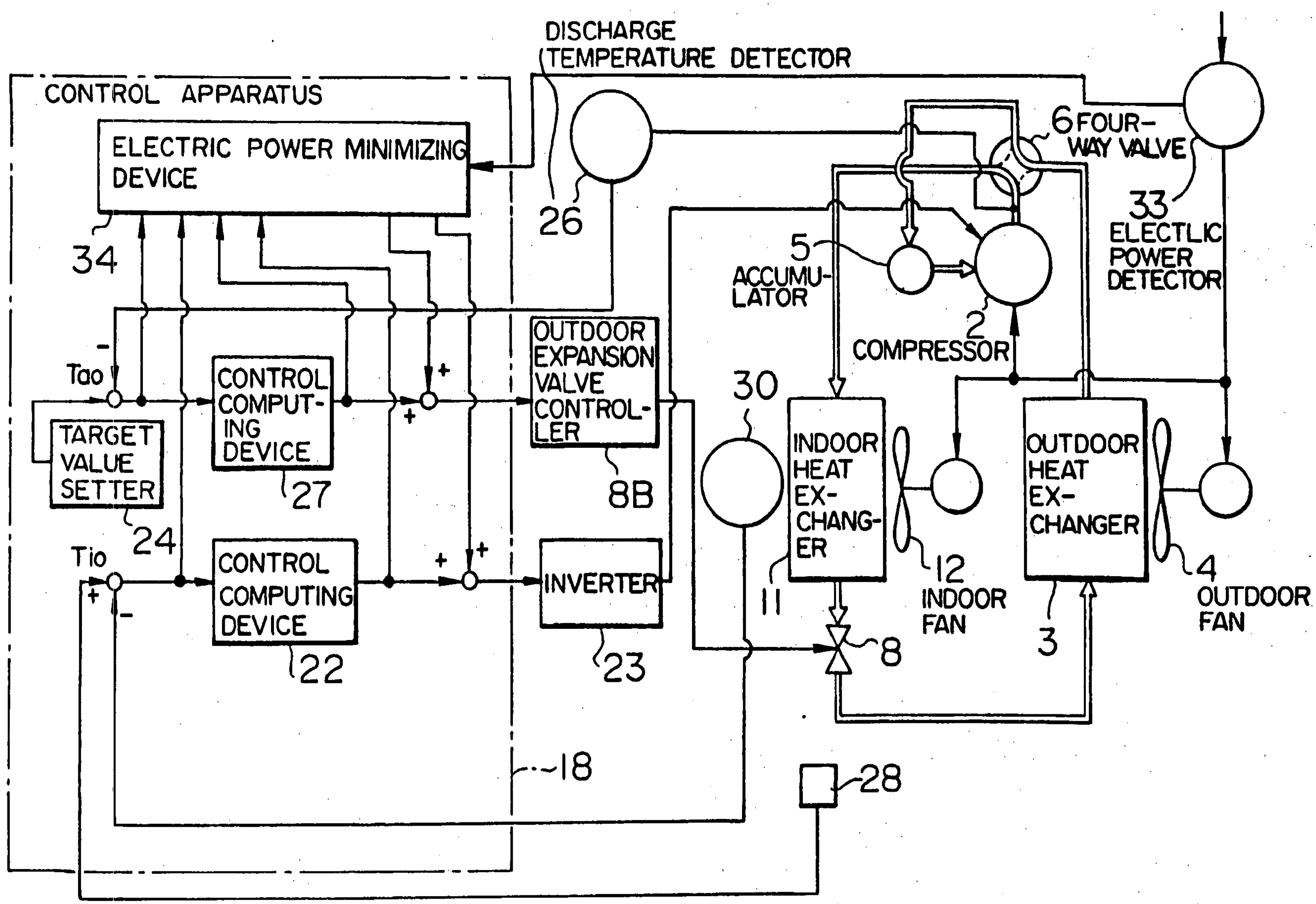

CONTROL APPARATUS
ELECTRIC POWER MINIMIZING DEVICE
34
DISCHARGE TEMPERATURE DETECTOR
26
6 FOUR-WAY VALVE
33 ELECTLIC POWER DETECTOR
5 ACCUMU-LATOR
2 COMPRESSOR
Tao
-
TARGET VALUE SETTER
24
CONTROL COMPUT-ING DEVICE
27
+
OUTDOOR EXPANSION VALVE CONTROL-LER
8B
30
INDOOR HEAT EX-CHANG-ER
11
12 INDOOR FAN
OUTDOOR HEAT EX-CHANGER
3
4 OUTDOOR FAN
8
Tio
CONTROL COMPUTING DEVICE
22
INVERTER
23
18
28

FIG. 4

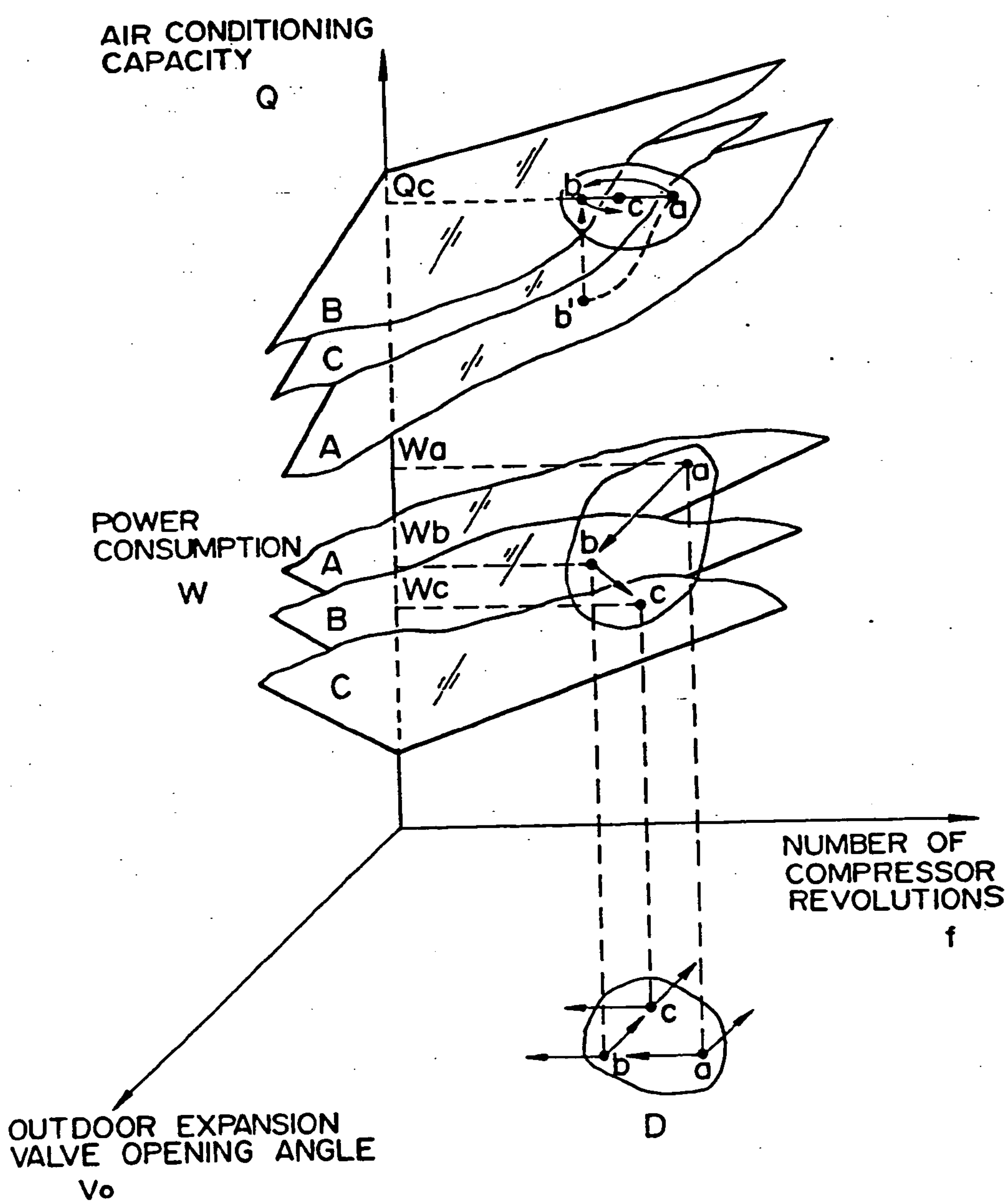

AIR CONDITIONING CAPACITY
Q
Qc
b
c
a
b'
B
C
A
Wa
POWER CONSUMPTION
W
Wb
Wc
A
B
C
a
b
c
NUMBER OF COMPRESSOR REVOLUTIONS
f
c
b
a
D
OUTDOOR EXPANSION VALVE OPENING ANGLE
Vo

FIG. 5

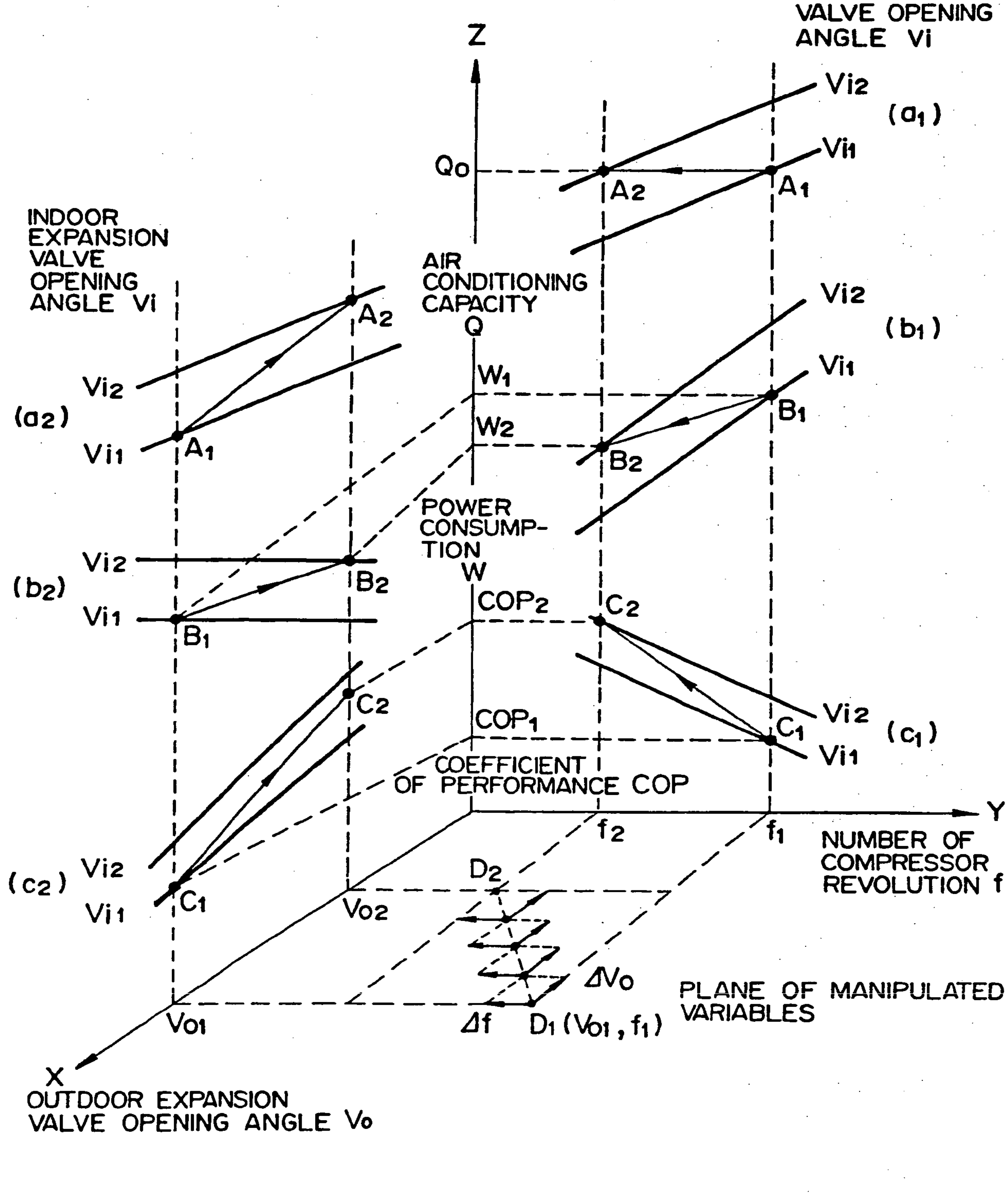

INDOOR
EXPANSION
VALVE OPENING
ANGLE Vi
Z
Vi2
(a1)
Vi1
Qo
A2
A1
INDOOR
EXPANSION
VALVE
OPENING
ANGLE Vi
AIR
CONDITIONING
CAPACITY
Q
A2
Vi2
(b1)
Vi1
Vi2
(a2)
Vi1
A1
W1
W2
B1
B2
POWER
CONSUMP-
TION
W
Vi2
(b2)
Vi1
B2
B1
COP2
C2
C2
Vi2
(c1)
COP1
C1
Vi1
COEFFICIENT
OF PERFORMANCE COP
Y
f2
f1
NUMBER OF
COMPRESSOR
REVOLUTION f
Vi2
(c2)
Vi1
C1
D2
Vo2
ΔVo
PLANE OF MANIPULATED
VARIABLES
Vo1
Δf
D1 (Vo1, f1)
X
OUTDOOR EXPANSION
VALVE OPENING ANGLE Vo

FIG. 6

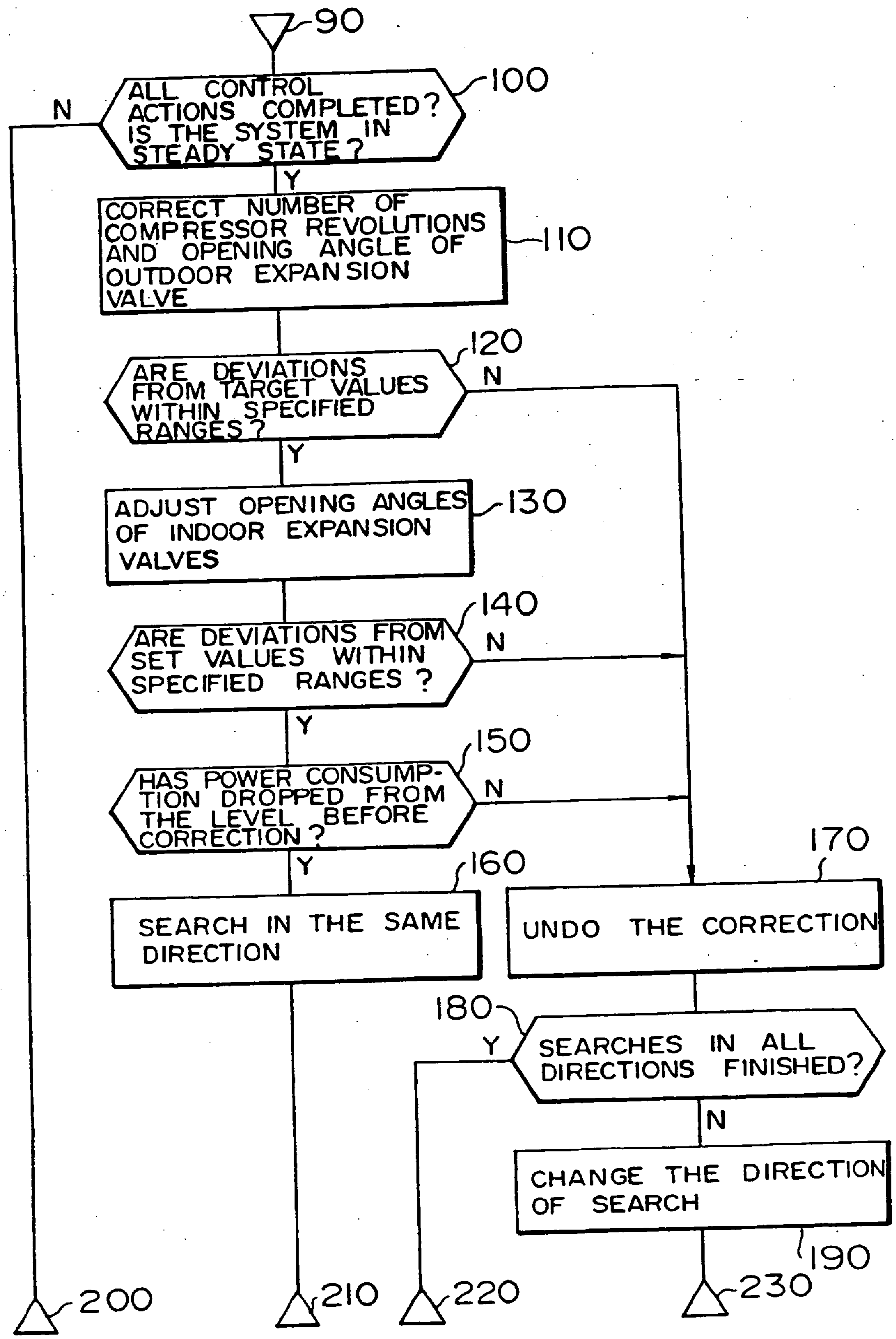

90
ALL CONTROL ACTIONS COMPLETED? IS THE SYSTEM IN STEADY STATE?
100
N
Y
CORRECT NUMBER OF COMPRESSOR REVOLUTIONS AND OPENING ANGLE OF OUTDOOR EXPANSION VALVE
110
ARE DEVIATIONS FROM TARGET VALUES WITHIN SPECIFIED RANGES?
120
N
Y
ADJUST OPENING ANGLES OF INDOOR EXPANSION VALVES
130
ARE DEVIATIONS FROM SET VALUES WITHIN SPECIFIED RANGES?
140
N
Y
HAS POWER CONSUMPTION DROPPED FROM THE LEVEL BEFORE CORRECTION?
150
N
Y
SEARCH IN THE SAME DIRECTION
160
UNDO THE CORRECTION
170
SEARCHES IN ALL DIRECTIONS FINISHED?
180
Y
N
CHANGE THE DIRECTION OF SEARCH
190
200
210
220
230

FIG.7

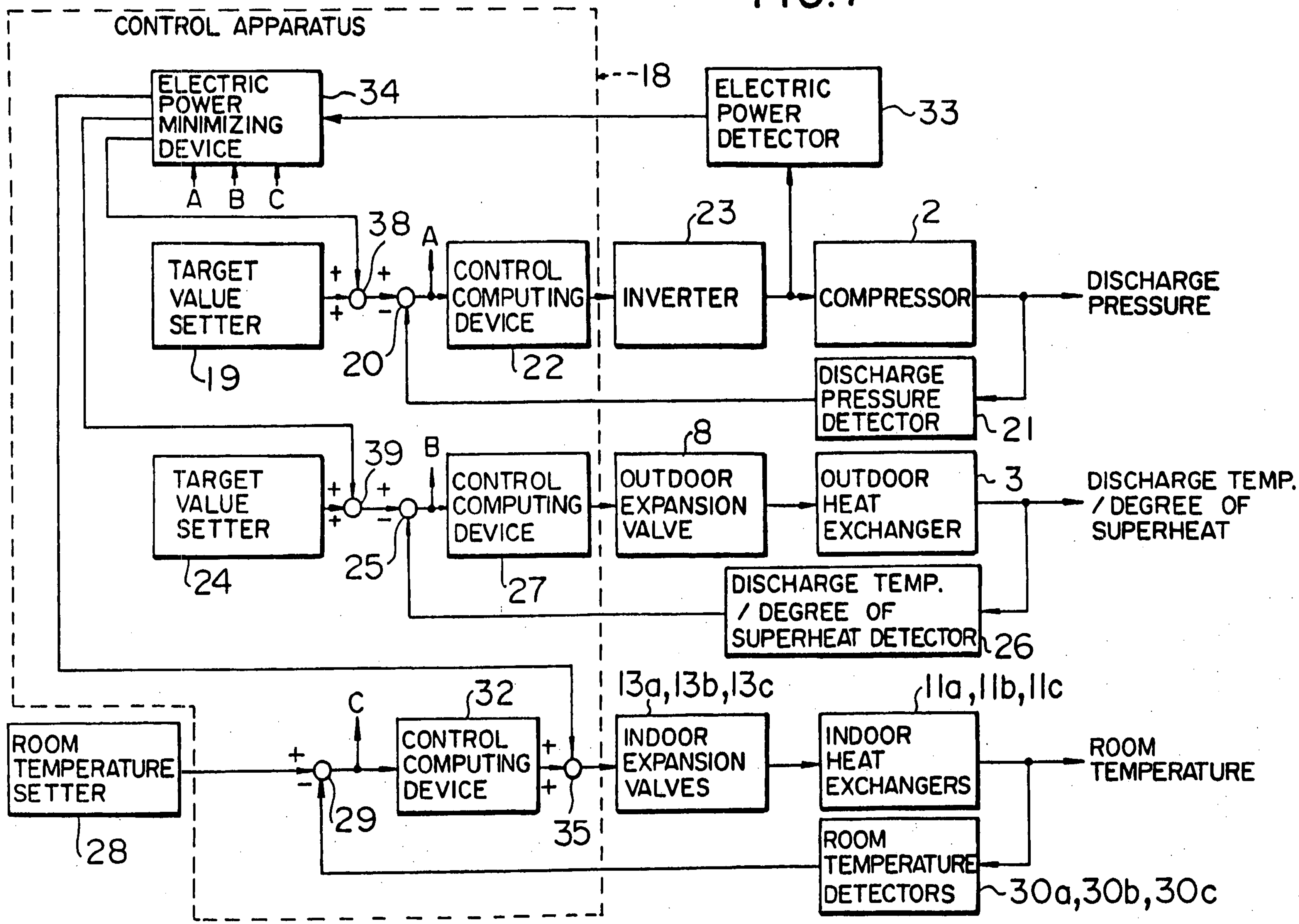

CONTROL APPARATUS
18
ELECTRIC POWER MINIMIZING DEVICE
34
A
B
C
ELECTRIC POWER DETECTOR
33
TARGET VALUE SETTER
19
38
20
A
CONTROL COMPUTING DEVICE
22
INVERTER
23
COMPRESSOR
2
DISCHARGE PRESSURE
DISCHARGE PRESSURE DETECTOR
21
TARGET VALUE SETTER
24
39
25
B
CONTROL COMPUTING DEVICE
27
OUTDOOR EXPANSION VALVE
8
OUTDOOR HEAT EXCHANGER
3
DISCHARGE TEMP. / DEGREE OF SUPERHEAT
DISCHARGE TEMP. / DEGREE OF SUPERHEAT DETECTOR
26
ROOM TEMPERATURE SETTER
28
29
C
CONTROL COMPUTING DEVICE
32
35
13a,13b,13c
INDOOR EXPANSION VALVES
11a,11b,11c
INDOOR HEAT EXCHANGERS
ROOM TEMPERATURE
ROOM TEMPERATURE DETECTORS
30a,30b,30c

FIG.8

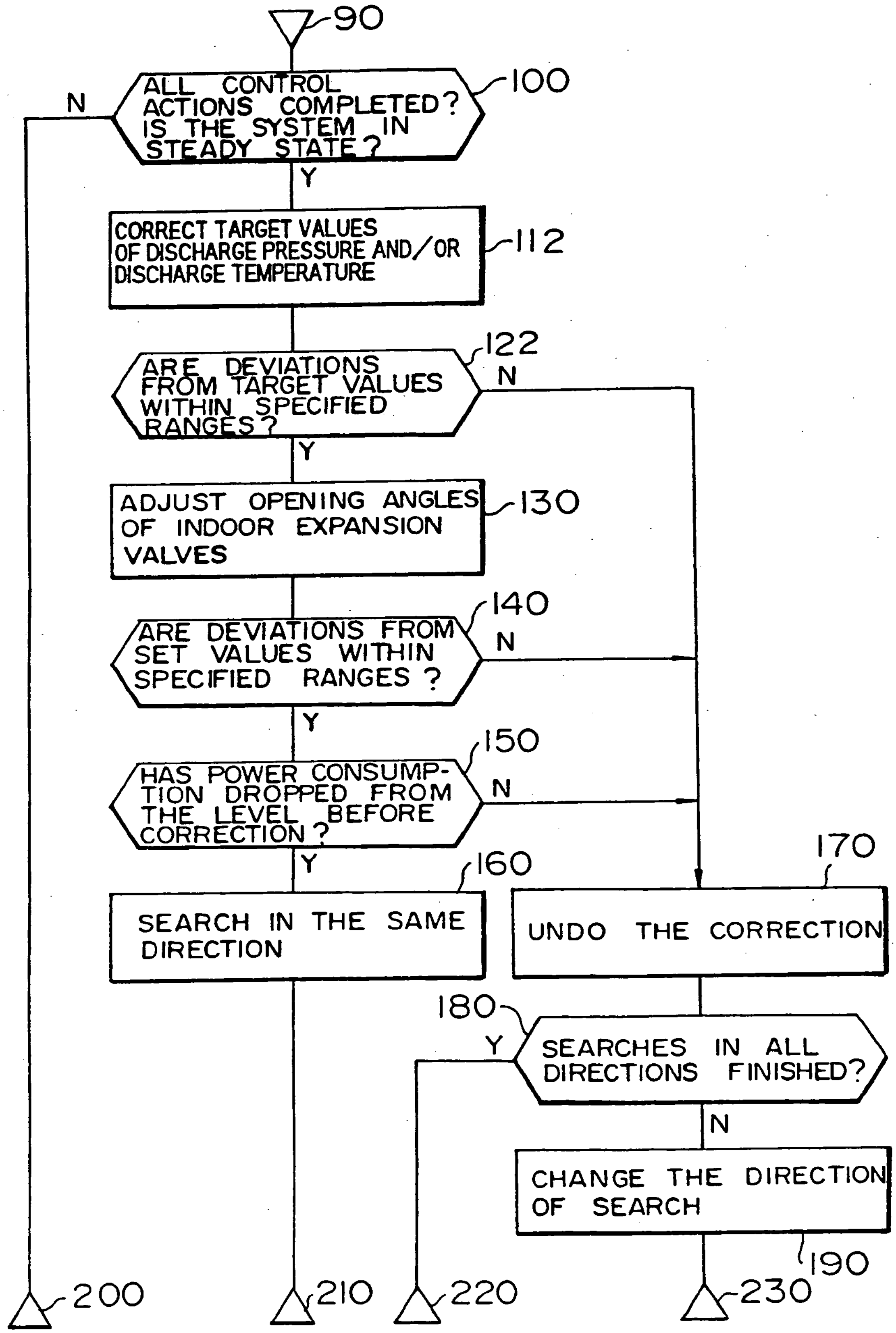

90
ALL CONTROL ACTIONS COMPLETED? IS THE SYSTEM IN STEADY STATE?
100
N
Y
CORRECT TARGET VALUES OF DISCHARGE PRESSURE AND/OR DISCHARGE TEMPERATURE
112
ARE DEVIATIONS FROM TARGET VALUES WITHIN SPECIFIED RANGES?
122
N
Y
ADJUST OPENING ANGLES OF INDOOR EXPANSION VALVES
130
ARE DEVIATIONS FROM SET VALUES WITHIN SPECIFIED RANGES ?
140
N
Y
HAS POWER CONSUMPTION DROPPED FROM THE LEVEL BEFORE CORRECTION ?
150
N
Y
SEARCH IN THE SAME DIRECTION
160
UNDO THE CORRECTION
170
180
SEARCHES IN ALL DIRECTIONS FINISHED?
Y
N
CHANGE THE DIRECTION OF SEARCH
190
200
210
220
230

FIG.9

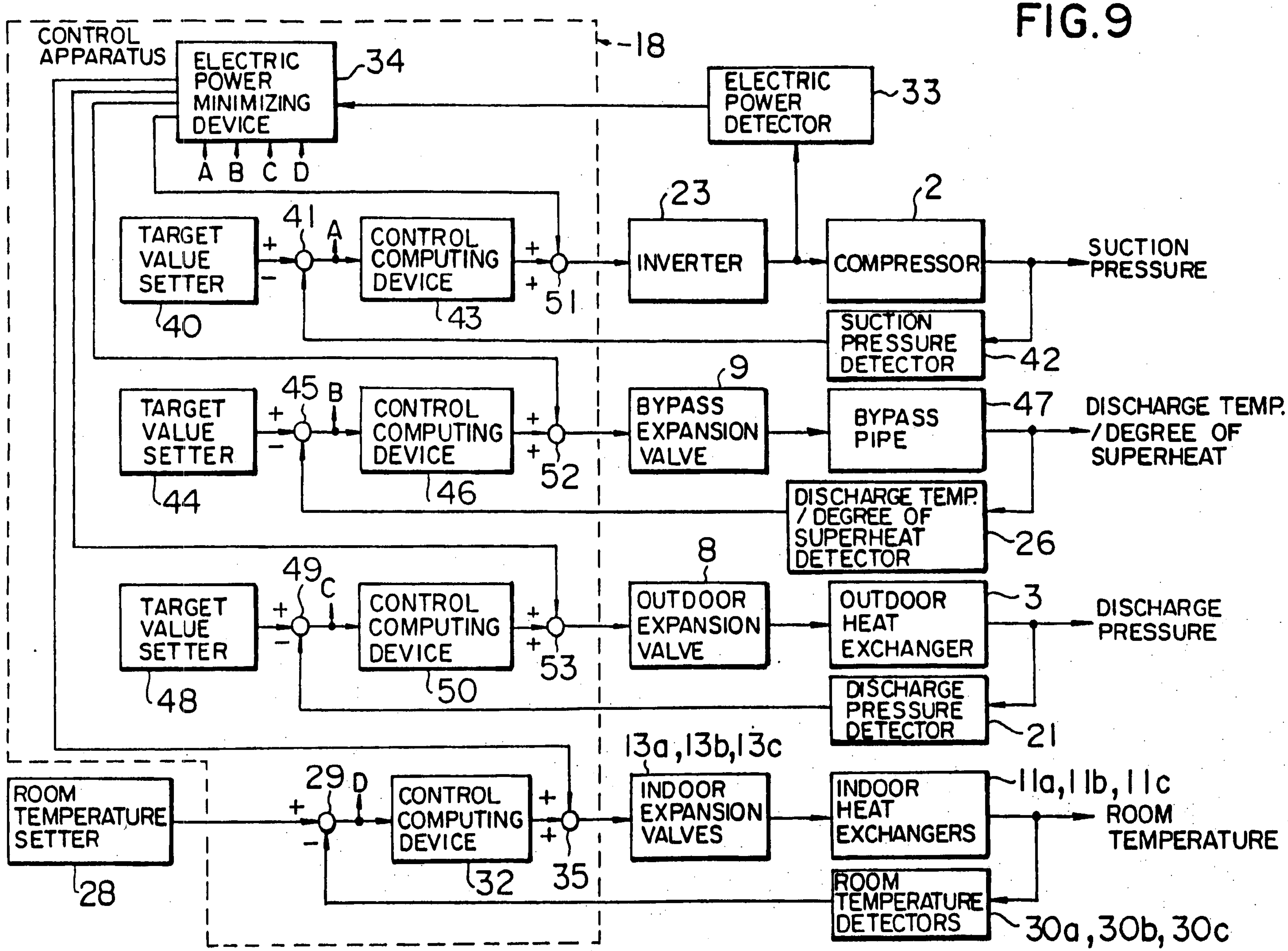

CONTROL APPARATUS
18
ELECTRIC POWER MINIMIZING DEVICE
34
A B C D
ELECTRIC POWER DETECTOR
33
TARGET VALUE SETTER
40
41
A
CONTROL COMPUTING DEVICE
43
51
INVERTER
23
COMPRESSOR
2
SUCTION PRESSURE
SUCTION PRESSURE DETECTOR
42
TARGET VALUE SETTER
44
45
B
CONTROL COMPUTING DEVICE
46
52
BYPASS EXPANSION VALVE
9
BYPASS PIPE
47
DISCHARGE TEMP. /DEGREE OF SUPERHEAT
DISCHARGE TEMP. / DEGREE OF SUPERHEAT DETECTOR
26
TARGET VALUE SETTER
48
49
C
CONTROL COMPUTING DEVICE
50
53
OUTDOOR EXPANSION VALVE
8
OUTDOOR HEAT EXCHANGER
3
DISCHARGE PRESSURE
DISCHARGE PRESSURE DETECTOR
21
ROOM TEMPERATURE SETTER
28
29
D
CONTROL COMPUTING DEVICE
32
35
13a,13b,13c
INDOOR EXPANSION VALVES
INDOOR HEAT EXCHANGERS
11a,11b,11c
ROOM TEMPERATURE
ROOM TEMPERATURE DETECTORS
30a,30b,30c

FIG. 10

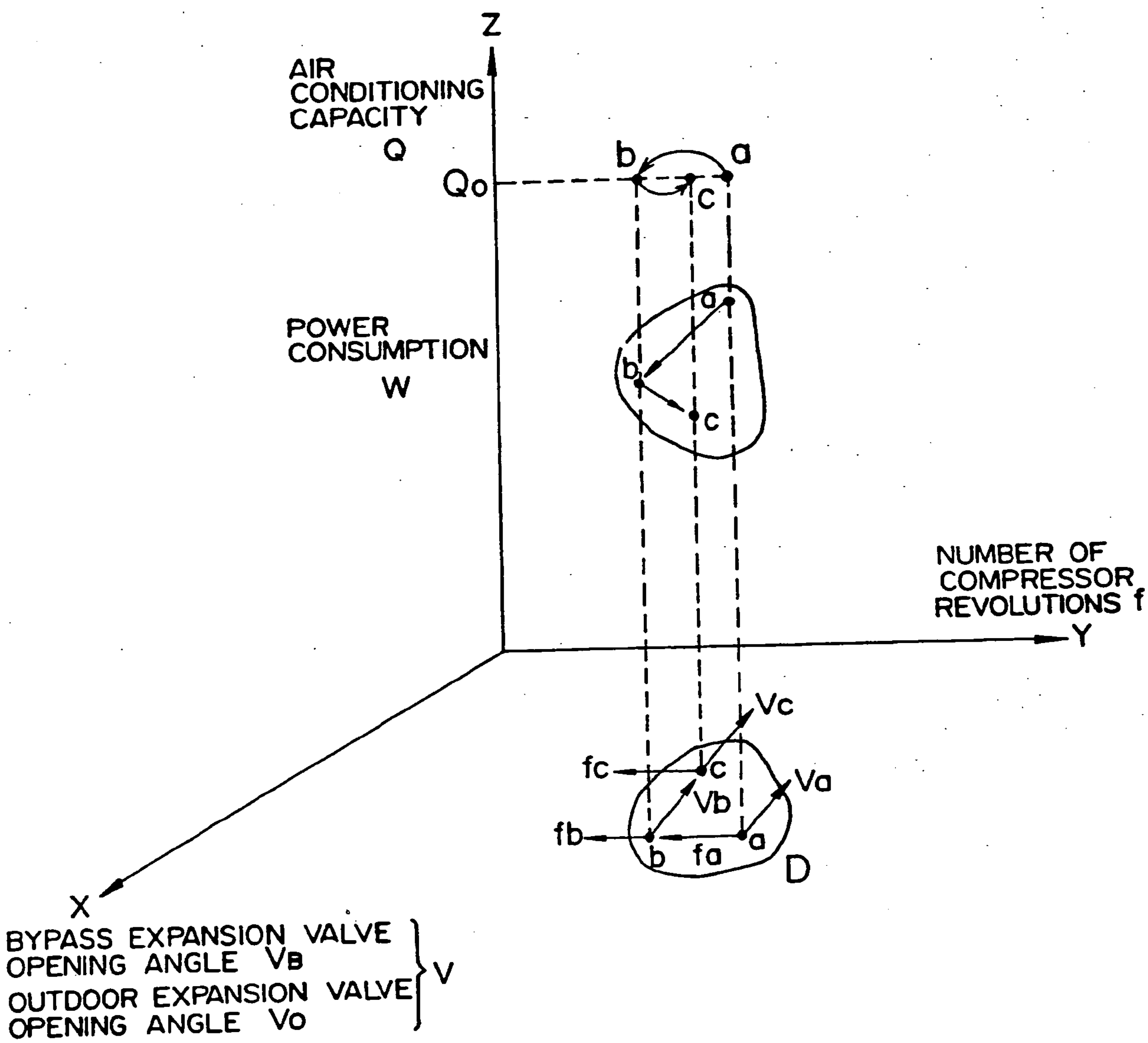

Z
AIR CONDITIONING CAPACITY Q
Qo
b
a
c
POWER CONSUMPTION W
a
b
c
NUMBER OF COMPRESSOR REVOLUTIONS f
Y
Vc
fc
c
Va
Vb
fb
b
fa
a
D
X
BYPASS EXPANSION VALVE OPENING ANGLE VB
OUTDOOR EXPANSION VALVE OPENING ANGLE Vo
V

FIG. 11

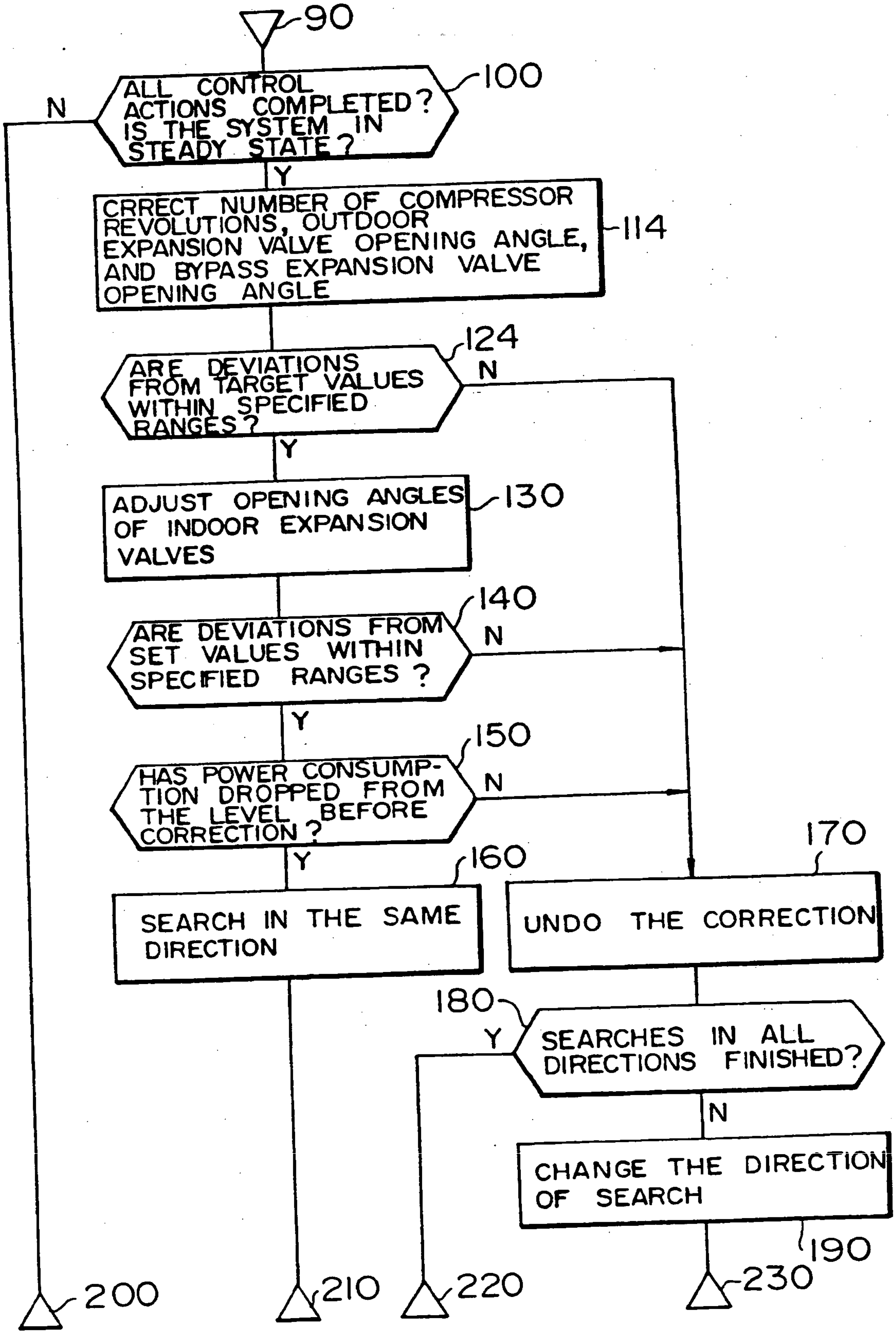
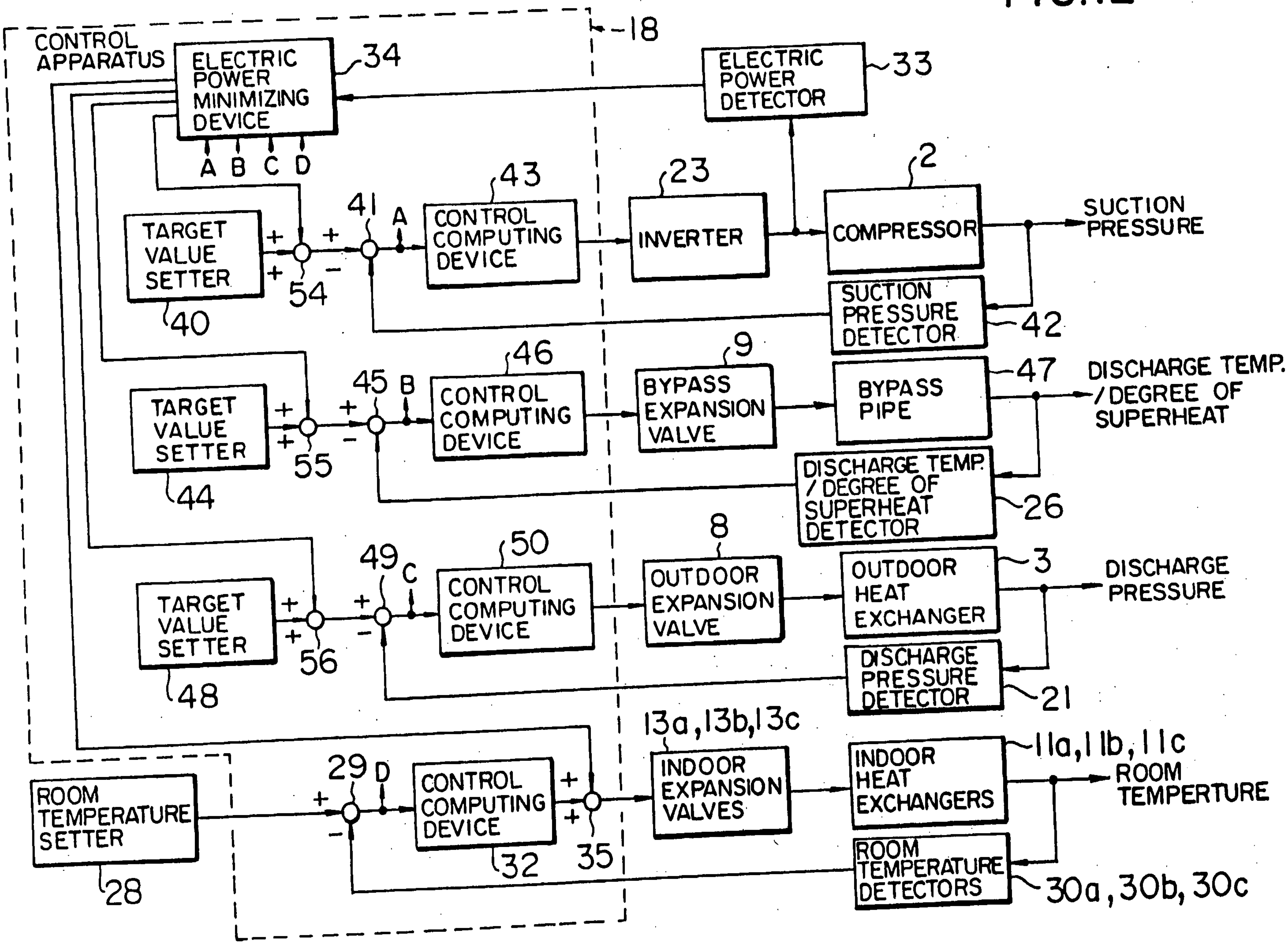

90
ALL CONTROL ACTIONS COMPLETED? IS THE SYSTEM IN STEADY STATE?
100
N
Y
CRRECT NUMBER OF COMPRESSOR REVOLUTIONS, OUTDOOR EXPANSION VALVE OPENING ANGLE, AND BYPASS EXPANSION VALVE OPENING ANGLE
114
ARE DEVIATIONS FROM TARGET VALUES WITHIN SPECIFIED RANGES?
124
N
Y
ADJUST OPENING ANGLES OF INDOOR EXPANSION VALVES
130
ARE DEVIATIONS FROM SET VALUES WITHIN SPECIFIED RANGES ?
140
N
Y
HAS POWER CONSUMPTION DROPPED FROM THE LEVEL BEFORE CORRECTION ?
150
N
Y
SEARCH IN THE SAME DIRECTION
160
UNDO THE CORRECTION
170
SEARCHES IN ALL DIRECTIONS FINISHED?
180
Y
N
CHANGE THE DIRECTION OF SEARCH
190
200
210
220
230

FIG.12


CONTROL APPARATUS
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ELECTRIC POWER MINIMIZING DEVICE
34
A B C D
ELECTRIC POWER DETECTOR
33
TARGET VALUE SETTER
40
54
41
A
CONTROL COMPUTING DEVICE
43
INVERTER
23
COMPRESSOR
2
SUCTION PRESSURE
SUCTION PRESSURE DETECTOR
42
TARGET VALUE SETTER
44
55
45
B
CONTROL COMPUTING DEVICE
46
BYPASS EXPANSION VALVE
9
BYPASS PIPE
47
DISCHARGE TEMP. / DEGREE OF SUPERHEAT
DISCHARGE TEMP. / DEGREE OF SUPERHEAT DETECTOR
26
TARGET VALUE SETTER
48
56
49
C
CONTROL COMPUTING DEVICE
50
OUTDOOR EXPANSION VALVE
8
OUTDOOR HEAT EXCHANGER
3
DISCHARGE PRESSURE
DISCHARGE PRESSURE DETECTOR
21
ROOM TEMPERATURE SETTER
28
29
D
CONTROL COMPUTING DEVICE
32
35
13a,13b,13c
INDOOR EXPANSION VALVES
INDOOR HEAT EXCHANGERS
11a,11b,11c
ROOM TEMPERTURE
ROOM TEMPERATURE DETECTORS
30a,30b,30c

FIG. 13

ROOM TEMPERATURE SET VALUE	DISCHARGE TEMPERATURE TARGET VALUE	NUMBER OF COMPRESSOR REVOLUTIONS	EXPANSION VALVE OPENING ANGLE
⋮	⋮	⋮	⋮
Tion	Tdon	fn	Vn
⋮	⋮	⋮	⋮

2287783

AIR CONDITIONING SYSTEM AND OPERATING METHOD THEREFOR

This invention relates to an air conditioning system and a method for operating this system, and more particularly to an air conditioning system and a method for operating this system utilizing electric energy efficiently.

In the conventional air conditioning systems, as shown in JP-A-63-25446 and JP-A-5-118609, attempts were made to minimize power consumption by controlling the room temperature by manipulating the number of compressor revolutions so as to approach its set or target value and controlling the degree of compressor superheat by manipulating the opening of the expansion valve so as to approach its set or target value, and at the same time manipulating the number of revolutions of indoor fans.

In conventional multi-room air conditioning systems, each having a plurality of indoor units connected by piping to one outdoor unit, as shown in JP-A-3-191265, JP-A-4-254161, JP-A-5-33986, and JP-A-5-93539, for example, the pressure of the compressor or the temperature of the outdoor heat exchanger of the outdoor unit and the temperatures of the heat exchangers of the indoor units were used as controlled variables, and in

order for the controlled variables to approach the predetermined set values according to the operating condition, manipulated variables such as the number of revolutions of the compressor and the opening angle of the expansion valve are controlled by commands from the control apparatus. By the control apparatus as mentioned above, a multi-room air conditioning system can be controlled so as to be always in an appropriate operating condition, the compressor operation and the refrigeration cycle can always be maintained in stable condition, and the air conditioning capacity can be adjusted so as to correspond to increases or decreases of the air conditioning load of the respective rooms. Therefore, the air conditioning system can always be maintained in a balanced operating condition with less energy losses.

However, in the former of the above-mentioned prior art, the direct object of control is to abide by the set value of room temperature and the target value of compressor superheat, so that nothing more than the function to perform stable control is provided. Moreover, since power consumption is minimized by manipulating only the number of revolutions the fans on the indoor unit side, there is a limit to minimization of power consumption. In other words, there is a possibility that power consumption by the whole of the air conditioning system is not minimized, and this is intolerable from the viewpoint of energy saving. In the latter of the prior art mentioned above, enough consideration was not taken

of power consumption of the multi-room type air conditioning system. For this reason, even if the air conditioning system has been operating stably and safely and, also, the users are enjoying a comfortable life, but viewed from a viewpoint of energy saving, this does not necessarily mean that the optimum operating condition has been achieved.

An object of the present invention is to provide an air conditioning system having a control apparatus so arranged as to decide manipulated variables to minimize the power consumption of the air conditioning system as the controlled variable, and also provide a method for controlling this air conditioning system.

Another object of the present invention is to reduce power consumption in the air conditioning system without sacrificing the comfortability for the users.

A further object of the present invention is to provide an air conditioning system superior in controllability, and a control method therefor.

A yet further object of the present invention is to provide an air conditioning system including control means for directly controlling power consumption or a coefficient of performance.

In a preferred mode of carrying out the present invention to achieve the above objects, an air conditioning system has an outdoor unit and at least one indoor

unit connected by piping, and control means for performing feedback control of controlled variables by using manipulated variables, the outdoor unit having a variable-revolution-speed compressor, an outdoor heat exchanger and an outdoor expansion valve sequentially connected by piping, said at least one indoor unit including an indoor heat exchanger, wherein for the control means, electric power detecting means for detecting the electric power consumed by the air conditioning system is installed to enable the control means to perform feedback control including control to minimize power consumption when deviations of the room temperatures or the air conditioning capacities of the indoor units from the target values are within specified ranges.

Preferably, each of the indoor units includes an indoor expansion valve, and the control means also controls the opening angle of the indoor expansion valve.

Furthermore, preferably, the control means includes a first feedback control portion for controlling the discharge pressure so as to approach the target value, a second feedback control portion for controlling the discharge temperature of the compressor so as to approach the target value, and a third control portion for controlling a plurality of room temperatures so as to approach the target values, and wherein the control means further includes an electric power control portion for receiving an electric power value detected by the electric power detecting means, and outputting correction

signals through adders into the feedback loops of the first to third feedback control portions.

Further, preferably, the control means includes a first feedback control portion for controlling the discharge pressure so as to approach the target value, a second feedback control portion for controlling the discharge temperature of the compressor so as to approach the target value, and a third feedback control portion for controlling a plurality of room temperatures so as to approach the target values, and the control means further includes an electric power control portion for receiving an electric power value detected by the electric power detecting means, outputting correction signals through adders to the feedback loops of the first and second feedback control portions, and also outputting a correction signal into the feedback loop of the third feedback control portion.

Further, preferably, the air conditioning system comprises discharge pressure detecting means for detecting the discharge pressure of the compressor, temperature detecting means for detecting the discharge gas temperature or the degree of superheat, electric power detecting means for detecting power consumption or current and voltage, room temperature detecting means for detecting the temperature of air flowing into the indoor units, setting means for setting the set values of room temperature or the target values of the air conditioning capacities of the indoor units, means for deciding the

target value of the discharge pressure of the compressor, number of revolutions computing means for computing the number of revolutions of the compressor to reduce the deviation of the discharge pressure detected by the discharge pressure detecting means from the target value thereof, number of revolutions control means for controlling the number of compressor revolutions based on the result of the computation, means for deciding the target value of the discharge gas temperature or the degree of superheat of the compressor, opening angle computing means for computing the opening angle of the outdoor expansion valve to reduce the deviation of the discharge gas temperature or the degree of superheat from the target value thereof, opening angle control means for controlling the opening angle of the outdoor expansion valve based on the result of the computation, and a control apparatus for, to further reduce power consumption of the multi-room air conditioning system detected by the electric power detector, putting deviations of the set values of room temperature or deviations of the air conditioning capacities of the indoor units in operation from the target values in specified ranges and putting a deviation of the compressor discharge pressure from the target value and a deviation of the discharge gas temperature or the degree of superheat from the target value in specified ranges, and executing at least either the correction of the number of compressor revolutions and the correction of

the outdoor expansion valve opening angle, or the correction of the target value of the compressor discharge pressure and the correction of the target value of the discharge gas temperature or the degree of superheat.

In another preferred mode of carrying out the present invention, an air conditioning system has an outdoor unit and at least one indoor unit connected by piping, the outdoor unit having a variable-revolution-speed compressor, an outdoor heat exchanger and an outdoor expansion valve sequentially connected by piping, the at least indoor unit having an indoor heat exchanger and an indoor expansion valve connected by piping, said air conditioning system comprising electric power detecting means for detecting power consumption of the air conditioning system, compressor temperature detecting means for detecting the discharge temperature of the compressor, room temperature detecting means for detecting the temperatures of air flowing into the indoor heat exchangers, and control means for controlling the number of compressor revolutions and the opening angles of the outdoor expansion valve and the indoor expansion valves, wherein the control means includes a first control portion for controlling the discharge pressure so as to approach the target value, a second control portion for controlling the discharge temperature of the compressor so as to approach the target value, and a third control portion for controlling a plurality of room temperatures so as to approach the target values, and wherein the

control means also includes an electric power control portion for receiving an electric power value detected by the electric power detecting means and outputting correction signals to the first to third control portions.

In still another preferred mode of carrying out the present invention, a method for controlling an air conditioning system for providing comfortable air-conditioned spaces by feedback control, the air conditioning system having an outdoor unit and at least one indoor unit connected by piping, the outdoor unit having a variable-revolution-speed compressor, an outdoor heat exchanger and an outdoor expansion valve sequentially connected by piping, and the at least indoor unit having an indoor heat exchanger and an indoor expansion valve connected by piping, the method for controlling the air conditioning system comprising the steps of:

after optimum air-conditioned spaces are obtained by feedback control using the discharge pressure and temperature of the compressor and the temperatures of air flowing into the indoor units, correcting at least either one of the number of compressor revolutions and the outdoor expansion valve opening angle;

adjusting the opening angles of the indoor expansion valve so that the room temperatures of the indoor units in operation are in a specified range when the detected value of the compressor discharge pressure or temperature is in a specified range;

comparing the power consumption of the air

conditioning system with the power consumption before the correction mentioned above; and

repeating the above procedure until the power consumption becomes minimum.

In the thus arranged air conditioning system according to the present invention, the measures taken to obtain comfortable air-conditioned spaces are the same as in prior art, that is, manipulated variables, such as the number of compressor revolutions and the expansion valve opening angle, are controlled in order that a plurality of controlled variables, including at least one of the discharge pressure, discharge temperature, suction pressure, and degree of discharge superheat of the compressor, along with the temperatures of the indoor heat exchangers or the temperature of the outdoor heat exchanger, agree with predetermined target values. Consequently, the whole air conditioning system can be controlled so as to be operated always in an appropriate operating condition, a stable and safe operation can be maintained, and at the same time the air conditioning capacity can be obtained which corresponds to an increase or decrease of load, and the air-conditioned spaces favorable to the users can be provided.

Moreover, in the air conditioning system according to the present invention, the manipulated variables or the target values for the above-mentioned controlled variables are corrected to minimize power consumption based on the directly detected power

consumption in such a way that the deviations from the set values of room temperature or the target values of the air conditioning capacities of a plurality of indoor units are within such specified ranges as not to impair the comfortability to the residents. Consequently, an advantageous operating condition from the energy saving point of view can be maintained at all times.

In the drawings:

Fig. 1 is a schematic diagram showing the configuration of a multi-room air conditioning system according to an embodiment of the present invention;

Fig. 2 is a block diagram showing the functions of a control apparatus of the embodiment shown in Fig. 1;

Fig. 3 is a schematic diagram showing the configuration of the air conditioning system according to another embodiment of the present invention;

Fig. 4 is a diagram for explaining the operation principle of the control apparatus according to the present invention;

Fig. 5 is a diagram for explaining the operation principle of the control apparatus according to the embodiment shown in Fig. 1;

Fig. 6 is a flowchart for explaining the control operation of the control apparatus in the embodiment shown in Fig. 1;

Fig. 7 is a diagram showing the functions of the control apparatus in a further embodiment of the

present invention;

Fig. 8 is a flowchart for explaining the control operation of the control apparatus in the embodiment shown in Fig. 7;

Fig. 9 is a block diagram showing the functions of the control apparatus in yet another embodiment of the present invention;

Fig. 10 is a diagram for explaining the operation principle of the control apparatus in the embodiment shown in Fig. 9;

Fig. 11 is a flowchart for explaining the control operation of the control apparatus in the embodiment shown in Fig. 9;

Fig. 12 is a block diagram showing the functions of the control apparatus in a still further embodiment of the present invention; and

Fig. 13 is a diagram for explaining combinations of manipulated variables in the present invention.

An embodiment of the present invention will be described with reference to the accompanying drawings. Description will start with a multi-room type air conditioning system and proceeds to a one-room type.

Fig. 1 is a schematic diagram of a multi-room air conditioning system. Reference numeral 1 denotes an outdoor unit installed outdoors which includes as basic elements a capacity-variable type compressor 2 with a

variable number of revolutions, an outdoor heat exchanger 3, and a variable-revolution-speed outdoor fan 4. In addition, as components to form a cooling/heating cycle for multi-room air conditioning, the outdoor unit further includes an accumulator 5, a four-way valve 6, a receiver 7 and an outdoor expansion valve 8 which controls the flow rate of refrigerant flowing into the outdoor heat exchanger. Furthermore, the outdoor unit has a bypass expansion valve 9 for supplying refrigerant from the receiver 7 to the compressor suction side while controlling the flow rate. Those components form a cooling/heating heat source cycle for multi-room air conditioning. This outdoor unit is connected with a plurality of indoor units 10a, 10b and 10c in parallel. In Fig. 1, a case of three rooms is described, but the present invention is not limited to three indoor units. The respective indoor units contain indoor heat exchangers 11a, 11b and 11c, variable-revolution-speed indoor fans 12a, 12b and 12c, and indoor expansion valves 13a, 13b and 13c for controlling the flow rates of the indoor heat exchangers. The outdoor unit 1 and the indoor units 10a, 10b and 10c are connected by a gas pipe 14, a gas branch pipe 15, and gas sub-branches 15a, 15b and 15c, a liquid pipe 16, a liquid branch pipe 17, and liquid sub-branches 17a, 17b and 17c.

The flow of refrigerant for heating the rooms is indicated by solid lines. In heating, the four-way valve 6 is in the state indicated by solid lines in Fig.

1, and a high-temperature high-pressure gas refrigerant discharged from the compressor 2 is sent through the gas pipe 14 to the indoor units 10a, 10b and 10c in operation. In the respective indoor units, the gas refrigerant condenses in the indoor heat exchangers 11a, 11b and 11c, thereby heating the rooms, and becomes a liquid refrigerant. Thereafter, the refrigerant passes through the liquid pipe 16 and returns to the receiver 7 of the outdoor unit 1. The liquid refrigerant, after coming out of the receiver 7, evaporates in the outdoor expansion valve 8 and the outdoor heat exchanger 3 to become a gas refrigerant, and returns through the accumulator 5 to the compressor 2.

On the other hand, in cooling the rooms, the flow of refrigerant is as indicated by broken lines. The four-way valve 6 is in the state shown by the broken lines, and the high-temperature and high-pressure gas refrigerant discharged from the compressor 2 condenses in the outdoor heat exchanger 3 and becomes a liquid refrigerant. After this, the liquid refrigerant passes through the receiver 7 and the liquid pipe 16, and is sent to the indoor units 10a, 10b and 10c in operation. In the respective indoor units, the liquid refrigerant evaporates in the indoor expansion valves 13a, 13b and 13c and the indoor heat exchangers 11a, 11b and 11c, thereby cooling the rooms, and becomes a gas refrigerant. Subsequently, the refrigerant passes through the gas pipe 14 and the accumulator 5 of the outdoor unit 1 and

returns to the compressor 2. In this process, the bypass expansion valve 9 is opened to bypass the liquid refrigerant to the suction side of the accumulator 5 to adjust the operating condition of the compressor 2.

In the multi-room air conditioning system as described, it is required to provide the users with comfortable air-conditioned environments by developing the air conditioning capacities suitable for the air conditioning load by controlling the indoor units while maintaining the compressor 2 in a safe and stable operating condition. In this embodiment, there are provided a plurality of feedback control functions each comprise detecting the controlled variables related to the above-mentioned requirement, and controlling the controlled variables so as to agree with the appropriate target values by using the manipulated variables. Those feedback control functions will be described in detail later.

Fig. 2 is a block diagram for explaining the functions of the control apparatus 18 in a heating cycle. In Fig. 2, those parts which are identical with those shown in Fig. 1 are designated by the same reference numerals. The compressor 2 has a feedback control function to control the discharge pressure and the discharge temperature so as to come closer to their target values. This function is as follows. Initially, an appropriate target value for the discharge pressure is set by a target value setter 19. Then, a subtracter 20 finds a

deviation of a detection signal of a discharge pressure detector 21 on the discharge side of the compressor 2 from the target value, and a computing device 22 computes the number of revolutions of the compressor 2, which reduces the deviation. The result of computation is output from the control apparatus 18 to an inverter 23 to control the number of revolutions of the compressor 2.

Similarly, a target value for the discharge temperature or the degree of discharge superheat is set by a target value setter 24. Then, a subtracter 25 finds a deviation of a detection signal of a discharge temperature detector or a degree of discharge superheat detector 26 on the discharge side of the compressor 2 from the target value, and a computing device 27 computes the opening angle of the outdoor expansion valve 8, which reduces the deviation. The result of computation is output from the control apparatus 18 to a controller of the outdoor expansion valve 8 to control the flow rate of the refrigerant flowing through the outdoor heat exchanger 3 in order to eventually adjust the discharge temperature or the degree of discharge superheat.

On the other hand, the indoor units 10a, 10b and 10c have a feedback control function to control their room temperatures or air conditioning capacities to come closer to the set values or the target values regardless of changes of load. The control function is as follows. At first, set values of room temperature are supplied from a room temperature setter 28. Then, a subtracter 29

obtains deviations of the detection signals of the room temperature detectors 30a, 30b and 30c installed on the suction sides of the indoor heat exchangers 11a, 11b and 11c from the set or target values, and a computing device 32 computes the opening angles of the indoor expansion valves 13a, 13b and 13c to reduce the deviations.

Instead of the room temperatures, it is also possible to control the air conditioning capacities of the indoor heat exchangers 11a, 11b and 11c. In this case, a possible process to this end is as follows: target value of the air conditioning capacities corresponding to the deviations of the room temperatures are decided, then, deviations from the above-mentioned target values are obtained for the detected values of the air conditioning capacities computed from differences between outputs from temperature detectors 30a, 30b and 30c on the inlet sides and outputs from temperature detectors 31a, 31b and 31c on the outlet sides of the indoor heat exchangers 11a, 11b and 11c, and the opening angles of the indoor expansion valves 13a, 13b and 13c, which reduce the above deviations, are obtained. The obtained opening angles are output from the control apparatus 18 to controllers of the indoor expansion valves 13a, 13b and 13c to control the flow rates of refrigerant flowing through the indoor heat exchangers 11a, 11b and 11c. In this manner, the room temperatures can be adjusted when the air conditioning capacities vary and the air conditioning loads vary.

In addition to the above-mentioned feedback control functions, the control apparatus in this embodiment also includes an optimizing control function for directly minimizing the power consumption of the air conditioning system. More specifically, the power consumption of the compressor 2 is detected by the electric power detector 33 or a current and voltage detector for detecting a current and a voltage equivalent to the electric power. Then, the minimizing computing device 34 for minimizing power consumption references at C in Fig. 2 deviations from the set values of room temperature at the indoor units in operation or deviations of the air conditioning capacities from the target values. To prevent the deviations from departing from a specified range, the opening angles of the indoor expansion valves 13a, 13b and 13c are corrected by an adder 35. Together with this, a deviation from the target value of the discharge pressure is referenced at A in Fig. 2, and a deviation from the target value from the discharge gas temperature or degree of superheat is referenced at B in Fig. 2, and in order that the power consumption is minimized without departure of the deviations from their specified ranges, the number of revolutions of the compressor 2 is corrected by an adder 36 and the opening angle of the outdoor expansion valve 8 is corrected by an adder 37.

When not only the power consumption of the compressor 2 but the power consumption of the whole air

conditioning system including the outdoor and indoor fans is to be minimized, an electric power detector 33 has only to be inserted into a power supply line leading to the air conditioning system.

Fig. 3 shows another embodiment of the present invention. In this embodiment, one difference from the above-described embodiment is that only one indoor unit is connected to an outdoor unit, but the other aspects of this embodiment are the same as in Figs. 1 and 2.

The principle of a method for directly reducing the power consumption will be described with reference to Fig. 4. For use as manipulated variables to directly minimize power consumption, there are two items considered adequate, namely, the number of compressor revolutions and the opening angle of the outdoor expansion valve. In addition, to maintain the air-conditioned environments in the rooms, it is also necessary to control the air conditioning capacity by manipulating the opening angles of the indoor expansion valves installed in the indoor units. The relation among the processes for adjusting those quantities and the resulting air conditioning capacity and power consumption is multidimensional, so that it is a matter of great difficulty to illustrate the relation by a diagram. The outline of the principle will be described using Fig. 4. In Fig. 4, the plane formed by the number of compressor revolutions f and the outdoor expansion valve opening angle v_o shows the manipulated variables to be corrected to minimize the

power consumption. The axis lying perpendicularly to this plane shows the conditioning capacity Q and the power consumption W in this order from above with respect to manipulated variables. The transition of state of a → b → c shows the process for searching a state where the power consumption is reduced by correcting the manipulated variables in units of specified amounts by following a predetermined procedure.

The region D is a region where the deviations from the target values of the discharge pressure and the discharge temperature as the controlled variables stay within the respective specified ranges, even if the number of compressor revolutions f and the outdoor expansion valve opening angle v_o are corrected from the optimum values. While the deviations are within this region D, the air conditioning system is in a stable condition as intended. It is also necessary to adjust the opening angles v_i of the indoor expansion valves to eliminate the possibilities that the deviations from the set values of temperature of the rooms where the indoor units in operation are installed or the deviations of the air conditioning capacities Q from the target values Q_o are go beyond the specified ranges, leaving the requirements of the residents unfulfilled and the comfortability reduced. Since there are a plurality of indoor units, the opening angle v_i of the indoor expansion valves are expressed using a combination of the indoor units as parameters.

$v_i = v_i\ (v_1, v_2, \ldots, v_n)$ .... (1)

where n denotes the number of an indoor unit in operation

In short, the expansion valve opening angles of the indoor units can be expressed mathematically by a space having n orthogonal axes. Hence, by setting the opening angles of the indoor expansion valves, a one-dimensional subspace is formed from the n-dimensional space. Therefore, by using the opening angles of the indoor expansion valves as the parameters, planes can be formed in Fig. 4 which are expressed by the following equations:

Plane A where state a exists : a combination of indoor expansion valves $v_{iA}=v_{iA}\ (v_{1A}, v_{2A}, \ldots, v_{nA})$

Plane B where state b exists : a combination of indoor expansion valves $v_{iB}=v_{iB}\ (v_{1B}, v_{2B}, \ldots, v_{nB})$

Plane C where state c exists : a combination of indoor expansion valves $v_{iC}=v_{iC}\ (v_{1C}, v_{2C}, \ldots, v_{nC})$

As a result, even if the state of the manipulation plane changes in such a manner as a → b → c, by adjusting the opening angles of the indoor expansion valves, the air conditioning capacity can be maintained at a fixed value Q_C. This will be described in greater detail with reference to Fig. 4.

Suppose that in the air conditioning system in

state a, the state a changes to state b by correcting the number of compressor revolutions as a manipulated variable by f_a. As for the air conditioning capacity, if the opening angles of the indoor expansion valves are kept unchanged, point a moves on plane A to point b'. In order to keep the air conditioning capacity at Q_c, which is at the same level as before the manipulated value was corrected, the opening angles of the expansion valves for the indoor heat exchangers are varied. Suppose that as a result, point b on plane B is one of the points which fulfill the above purpose. As for the power consumption at this time, the power consumption, which was at Wa when the state was at a, decreases to Wb as the state changes to b.

When the state is at b, the opening angle of the outdoor expansion is corrected by v_b. In this case, too, as has been done before, the opening angles of the indoor expansion valves to keep the air conditioning capacity Q_c unchanged are obtained. Suppose that the combination of those opening angles is point c on plane C. The power consumption at this time is Wc, that is, further lower than the power consumption Wb in state b. Suppose that in state c even if the number of compressor revolutions f_c and the opening angle v_c are corrected and the combination of the indoor expansion valves is adjusted, the power consumption does not decrease or the controlled variables such as the compressor discharge pressure are unable to stay within the permissible range.

At this time, the search for a possible reduction of electric energy consumed is terminated.

Description will next be made of a method for actually reducing power consumption based on the principle described above. In Fig. 5, of the two characteristic quantities, the Y axis is selected to represent the number of revolutions f of the compressor 2, and the X axis is selected to represent the opening angle v_o of the outdoor expansion valve 8, so that an X-Y plane thus formed is a plane of a combination of the manipulated variables. In addition, the Z axis is selected for a quantity representing the operating condition of the air conditioning system. The quantities represented on the Z axis are the air conditioning capacity Q of each indoor unit, and the power consumption W and the coefficient of performance COP of the air conditioning system in this order from above. In Fig. 5, the graphs denoted by (a1), (b1) and (c1) have the curves formed by projecting the curves of the X-Y-Z three-dimensional space to the Y-Z plane, while the graphs denoted by (a2), (b2) and (c2) have the curves formed by projecting the above-mentioned curves to the X-Z plane.

When the set values of the room temperature are given to the indoor units 10a, 10b and 10c, deviations of the detected room temperatures from the set values or the air conditioning capacities Q_o corresponding to the room temperature deviations are controlled by adjusting the opening angles v_i of the indoor expansion valves 13a, 13b

and 13c. Fig. 5 shows the operating condition of the air conditioning system by using as a parameter the opening angle of the indoor expansion valve of one room as an example. A graph (a_1) shows the relation between the number of compressor revolutions f and the air conditioning capacity Q by using the opening angle v_i of the indoor expansion room as the parameter. On the other hand, a graph (a_2) shows the relation between the opening angle v_o of the outdoor expansion valve 8 and the air conditioning capacity Q by using the opening angle v_i of the indoor expansion valve as the parameter. When the number of revolutions of the compressor 2 is f_1 and the opening angle of the outdoor expansion valve 8 is v_{o1}, if the opening angle of the indoor expansion valve is v_{i1}, the air conditioning capacity at point A_1 is Q_o. However, even if the number of revolutions of the compressor 2 is f_2 and the opening angle of the outdoor expansion valve 8 is v_{o2}, by setting the opening angle of the indoor expansion valve at v_{i2}, the air conditioning capacity at point A_2 can be retained at the same level of Q_o as before.

At this time, the relation between the number of revolutions f of the compressor 2 and the power consumption W is expressed as shown in a graph (b_1) by using the opening angle v_i of the indoor expansion valve as a parameter. Also, the relation between the opening angle v_o of the outdoor expansion valve 8 and power consumption W is expressed as shown in a graph (b_2) by using the

opening angle v_i of the indoor expansion valve as a parameter. The power consumption is W_1 at point B_1, which corresponds to the above-mentioned point A_1 reached when the number of revolutions of the compressor 2 is f_1, and also, the opening angle of the outdoor expansion valve 8 is v_{o1} and the opening angle of the indoor expansion valve is v_{i1}. However, the power consumption is W_2 at point B_2, which corresponds to the above-mentioned point A_2 reached when the number of revolutions of the compressor 2 is f_2, the opening angle of the outdoor expansion valve 8 is v_{o2} and, and in addition, the opening angle of the indoor expansion valve is set at v_{i2}. To be more specific, to obtain the same air conditioning capacity Q_o, the latter case requires a lesser level of power consumption W than in the former case.

Note that a coefficient of performance COP is a value obtained by dividing the air conditioning capacity Q by power consumption W, and is inverse proportion merely to power consumption when the air conditioning capacity is fixed at Q_o. Hence, the relation between the number of revolutions f of the compressor 2 and the coefficient of performance COP is expressed as shown in a graph (c_1) by using the opening angle v_i of the indoor expansion valve as a parameter. The relation between the opening angle v_o of the outdoor expansion valve 8 and the coefficient of performance COP is expressed as shown in a graph (c_2) by using the opening angle v_i of the indoor

expansion valve as a parameter. The coefficient of performance COP is COP_1 at point C_1 which corresponds to the above-mentioned point A_1 reached when the number of revolutions of the compressor 2 is f_1 and the opening angle of the outdoor expansion valve 8 is v_{o1} and the opening angle of the indoor expansion valve is set at v_{i1}. On the other hand, the coefficient of performance is COP_2 at point C_2, which corresponds to the above-mentioned point A_2 reached when the number of revolutions of the compressor 2 is f_2, the opening angle of the outdoor expansion valve 8 is v_{o2} and the opening angle of the indoor expansion valve is set at v_{i2}. To be more specific, the coefficient of performance COP is higher for the latter case than in the former case when the same air conditioning capacity Q_o is obtained.

Let us consider the above-mentioned process in relation to the plane of manipulated variables (the X-Y plane). A state $D_1(v_{o1}, f_1)$ when the number of revolutions of the compressor 2 is f_1 and the opening angle of the outdoor expansion valve 8 is v_{o1} is taken as a start point. By starting from the power consumption W_1 at this point D_1, the number of revolutions f of the compressor 2 and the opening angle v_o of the outdoor expansion valve 8 are varied by infinitesimal quantities Δf and Δv_o, respectively, and the quantities are computed. And, the direction in which the power consumption W is further reduced is searched. Assuming that the minimum power consumption W_2 is achieved in state D_2

(v_{o2}, f_2) when the number of revolutions of the compressor 2 is f_2 and the opening angle of the outdoor expansion valve is v_{o2}, then, power consumption corresponding to $W_1 - W_2$ can be saved.

Here, it is necessary to control the opening angles v_i of the indoor expansion valves to eliminate the possibilities that either the deviation from the set value of the temperature of the room where the indoor unit in operation is installed or the deviation of the air conditioning capacity Q from the target value goes beyond the specified range as shown in graphs (a_1) and (a_2), leaving the requirements of the residents unfulfilled and the comfortability decreased. In addition, though not illustrated, it is necessary to correct the number of revolutions f of the compressor 2 and the opening angle v_o of the outdoor expansion valve to eliminate possibilities that a deviation from the target value of either the discharge gas temperature or the degree of superheat of the compressor 2 is unable to stay within the a specified range, causing a hitch in the continuation of a normal operation of the compressor. To this end, as shown in Fig. 2, in controlling power consumption, a detection signal from the electric power detector 33 or from a voltage and current detector is input into the control apparatus. Other data to be input to the control apparatus are a deviation from the set value of room temperature or a deviation from the target value of the air conditioning capacity, a deviation from

the target value of detected pressure and a deviation from the target value of discharge temperature or degree of superheat.

Fig. 6 is a flowchart showing a procedure for directly minimizing power consumption as shown in Fig. 5, and describes the operation of the minimizing computing device 34. To ensure correct settings of the condition and power consumption of the multi-room air conditioning system, at the first step (step 90), the number of revolutions of the compressor 2 is controlled so that the discharge pressure of the compressor 2 reaches the target value, and next the opening angle of the outdoor expansion valve 8 is controlled so that the discharge temperature or the degree of discharge superheat of the compressor 2 reaches the target value. Subsequently, the opening angles of the indoor expansion valves 13a, 13b and 13c are controlled to make the room temperature or the air conditioning capacity of each room come closer to the target value, and under the steady state that all control actions have been completed (step 100), a search action is started. The steady state can be determined by a fact that the deviations of the above-mentioned controlled variables from the target values are within specified ranges for specified time periods (step 200).

Under this state, by following a specified procedure, at least either one of the two manipulated variables, that is, the number of compressor revolutions and the outdoor expansion valve opening angle, is

corrected by a specified amount (step 110). Thereafter, a waiting time is provided to wait for the air conditioning system to return to the steady state. When the multi-room air conditioning system has returned to the steady state, a decision is made whether the deviations of detected values from the target values of the discharge pressure, temperature or degree of superheat of the compressor 2 stay within specified ranges (step 120). If those deviations go beyond within the specified ranges, the correction done as mentioned above is inadequate and, therefore, the correction is cancelled (step 170), and the contents of the correction are changed (steps 180 and 190). If the deviations are within the specified ranges, the opening angles of the indoor expansion valves are adjusted so that the deviations of the detected room temperatures from the set values or the deviations of the measured air conditioning capacities from the target values in the indoor units in operation come into the specified range (step 130). Then, a decision is made whether the deviations are within the specified range (step 140), and if the deviations exceed the specified range, it follows that the correction mentioned above is still inadequate, so that the correction is cancelled, and the contents of the correction are changed (steps 170 to 190). If the deviations are within the specified range, whether power consumption after the correction has decreased from the level before the correction is examined (step 150). If

the power consumption has not decreased, the correction done as mentioned above is still inadequate, so that the correction is cancelled, and the contents of the correction are changed (steps 170 to 190). If the power consumption has decreased, this means that the above correction was successful in minimizing the power consumption, and that there is still a possibility of further decreasing the power consumption, so that it is advantageous to repeat the correction with the same contents as in the above correction (step 160). However, if the power consumption does not decrease as mentioned above by correction done with contents by any other specified procedures, a decision is made that the current state has the minimum power consumption, and the correction procedure is finished (steps 210 to 230).

Incidentally, it is possible to predetermine the procedure for correcting the two manipulated variables, that is, the number of compressor revolutions and the opening angle of the outdoor expansion valve 8, and also predetermine amounts of correction based on the characteristics of the multi-room air conditioning system shown in Fig. 5. More specifically, since the direction in which power consumption decreases can be predicted from Fig. 5, if a procedure is formulated such that correction of the manipulated variables proceeds in a predicted direction, correction is not a trial and error operation, but an operation that can achieve the minimization of electric power in a short time. This

will be further considered on the plane of manipulated variables in Fig. 5. If a search is started from the point of state D_1, a search is repeated in the direction of reducing power consumption by increasing or decreasing the number of revolutions of the compressor 2 in predetermined units of Δf in the predicted direction, or by using this method in combination with correction by increasing or decreasing the opening angle of the outdoor expansion valve 8 in predetermined units of Δv_0 similarly in the predicted direction. By this arrangement, a search proceeds in the direction of the point of state D_2, and on reaching the point D_2, the search is terminated, and thus the minimization of power consumption is achieved. It is possible to change the direction of a search only to the X direction or the Y direction or change the search direction to the X direction and the Y direction simultaneously, or a combination of these two methods. It is also possible to change the amount of correction in one correction or change the direction of increasing or decreasing the amount of correction. In this way, various heuristic methods can be employed to achieve efficient searches.

In the present invention, the room temperature is used as a rule of thumb for measuring comfortability. If, for example, 20°C was the optimum temperature in terms of conventional measure of comfort for a comfortable temperature range of ±2°C, a permissible error range of 18°C to 22°C was selected, and so long as the room

temperature was within this range, it used to be considered acceptable. In the present invention, however, even if the permissible range of comfortable temperature is in the same range of ±2°C as it used to be, a room temperature value to be selected is a point in temperature, so that the room temperature is controlled so as to be 19°C±0.1°C. If the operating condition changes, the room temperature under control varies within 21°C±0.1°C, for example.

In the above description, a multi-room type air conditioning system has been taken up as an example, but this invention can be applied similarly to a single-room type. In the latter case, since there is only one indoor unit, the indoor expansion valve to be controlled is naturally one.

Fig. 7 is a block diagram of a further embodiment of the present invention, and is a modification of the embodiment in Fig. 2. In Fig. 7, those parts designated by the same reference numerals as in Fig. 2 are the same parts. The basic feedback functions shown in Fig. 2 can be performed also in the embodiment in Fig. 7. In this embodiment, the function of the minimizing computing device 34 for directly minimizing power consumption differs from the one in Fig. 2 as described below. To be more concrete, the difference from the embodiment in Fig. 2 is that in minimizing power consumption, instead of using the manipulated variables such as the number of compressor revolutions and the opening

angle of the outdoor expansion valve 8, in this embodiment the target value of the discharge pressure of the compressor 2 is corrected by an adder 38 and the target value of the discharge temperature or the degree of superheat of the compressor 2 is corrected by an adder 39.

Fig. 8 is a flowchart for explaining the control operation of the electric power minimizing device 34. A difference from the control operation in Fig. 6 is that the target value of the discharge pressure or the target value of the discharge temperature or the degree of superheat is corrected in units of specified amount by following a predetermined procedure (steps 112 and 122) to search for a direction in which power consumption is decreased. Except for this difference, the other aspects of the general operating procedure are the same.

Fig. 9 is a block diagram for explaining the function of the control apparatus 18 in room cooling in a yet another embodiment of the present invention. In Fig. 9, those parts designated by the same reference numerals as in Figs. 1 and 2 are the same parts. With regard to the compressor 2, there is provided a feedback control function for controlling three state quantities, namely, the suction pressure, the discharge temperature or the degree of discharge superheat, and the discharge pressure so as to follow the target values. This function will be described. First, an adequate target value of suction pressure is given from a target value setting function

40. Then, a subtracter 41 obtains a deviation of the detection signal of a suction pressure detector 42 installed on the suction side of the compressor 2 from the target value, and a computing device 43 computes the number of revolutions of the compressor 2 so as to reduce this deviation. The result of this computation is output from the control apparatus 18 to the inverter 23 to rotate the compressor 2 for a specified number of revolutions.

Similarly, a target value of the discharge temperature or the degree of discharge superheat of the compressor 2 is given by a target value setter 44. Then, a subtracter 45 obtains a deviation from the target value of a detection signal of the discharge temperature detector 26 or a discharge superheat detector installed on the discharge side of the compressor 2, and a computing device 46 computes the opening angle of the bypass expansion valve 9 to reduce the above-mentioned deviation. The result of computation is output from the control apparatus 18 to the bypass expansion valve 9 to make the opening angle thereof comply with the specified value, thus controlling the flow rate of refrigerant flowing through a bypass pipe 47, thereby adjusting the discharge temperature or the degree of discharge superheat of the compressor 2. In addition, an adequate target value of discharge pressure of the compressor 2 is supplied by a target value setter 48. Then, a subtracter 49 obtains a deviation from this target value of a

detection signal of the discharge pressure detector 21 installed on the discharge side of the compressor 2, and a computing device 50 computes the opening angle of the outdoor expansion valve 8 to reduce the deviation. The result of computation is output from the control apparatus 18 to the outdoor expansion valve to make the opening angle of the outdoor expansion valve 8 comply with the specified value, thus controlling the flow rate of refrigerant flowing through the outdoor heat exchanger 3, thereby adjusting the discharge pressure of the compressor 2.

With regard to the indoor units 10a, 10b and 10c, the control apparatus 18 includes a feedback control function for controlling the room temperatures or the air conditioning capacities so as to follow the set values or target values regardless of load changes. This function will be described. First, set values of temperature of the respective rooms are given from the room temperature setter 28 by the user. Then, a subtracter 29 obtains deviations of detection signals of the room temperature detectors 30a, 30b and 30c installed on the suction sides of the indoor heat exchangers 11a, 11b and 11c from the set values, and the computing device 32 computes the opening angles of the indoor expansion valves 13a, 13b and 13c to reduce the deviations. The result of computation is output from the control apparatus 18 to the indoor expansion valves 13a, 13b and 13c, thus controlling the flow rates of refrigerant flowing through

the indoor heat exchangers 11a, 11b and 11c, thereby adjusting the room temperatures or the air conditioning capacities.

In addition to the above-mentioned feedback control function, the control apparatus 18 in this embodiment includes a feedback control function for directly minimizing power consumption. To perform this function, there is provided an electric power detector 33 or a current and voltage detector to detect the power consumption of the compressor 2. Control of the following processes is performed in parallel to minimize power consumption by using the minimizing computing device 34. To be more specific, to prevent the room temperatures by the indoor units in operation from departing from the given set values or to prevent the air conditioning capacities from departing from the given target values, the opening angles of the indoor expansion valves 13a, 13b and 13c are corrected by the adder 35 while referencing the deviations at D in Fig. 9. Also, to prevent the deviation of the suction pressure of the compressor 2 from the target value from departing from the specified range, the number of revolutions of the compressor 2 is corrected by an adder 51 while referencing the deviation at A in Fig. 9. Furthermore, to prevent the deviation of the discharge temperature or the degree of superheat of the compressor 2 from the target value from departing from the specified range, the opening angle of the bypass expansion valve 9 is corrected by an adder 52 while

referencing the deviation at B in Fig. 9. In addition, to prevent the deviation of the discharge pressure of the compressor 2 from the target value from departing from the specified range, the opening angle of the outdoor expansion valve 8 is corrected by an adder 53 while referencing the deviation at C in Fig. 9. Control of those corrections is performed in parallel by the minimizing computing device 34.

With reference to Fig. 10, description will now be made of the principle of minimizing power consumption based on the characteristics of the multi-room air conditioning system using the above-mentioned computing device 34. The X-Y plane is the plane of manipulated variables to be corrected to minimize electric power, which include the number of revolutions of the compressor 2, the opening angle v_B of the bypass expansion valve 9, and the opening angle v_O of the outdoor expansion valve 8. The Z axis represents the air conditioning capacity Q and power consumption W in this order from above. The transition of state of a $\rightarrow$ b $\rightarrow$ c indicates the process for searching the state whereby to reduce electric power, and the manipulated variables are corrected in units of specified amount by a predetermined procedure. The region D is a region where deviations of the suction pressure, discharge temperature and discharge pressure from their target values are within the specified ranges and the air conditioning system is in a stable condition as planned. Even when the state changes in such a manner

as a → b → c, by adjusting the opening angles of the indoor expansion valves, the air conditioning capacity is maintained at a fixed level, so that the comfort of the residents is not affected. Under this condition, if in state a the number of compressor revolutions is corrected by f_a, the state a as changes to state b where power consumption is reduced. If in state b the bypass expansion valve and the outdoor expansion valve are corrected by v_b, the state b changes to state c where power consumption is further reduced. In the state c, in whatever amount the manipulated variables, such as the number of compressor revolutions f_c and the bypass expansion valve opening angle v_c, are corrected, if the power consumption does not decrease or any of the manipulated variables goes beyond the specified range, a decision is made that search has reached the final state.

Fig. 11 is a flowchart for explaining the operation of the minimizing computing device 34 shown in Fig. 10. This control operation differs from that shown in Fig. 6 in that in addition to the number of compressor revolutions, the opening angle of the bypass expansion valve and the opening angle of the outdoor expansion valve are corrected in units of specified amount by the procedure in Fig. 10 (steps 114 and 124) to search for the direction in which electric power is reduced. The other aspects of the operating procedure are the same.

Fig. 12 is a block diagram of a still further embodiment of the present invention, which is a

modification of the embodiment in Fig. 9. In Fig. 12, those parts designated by the same reference numerals as in Fig. 9 are the same parts. In this embodiment, too, there is provided a basic feedback function shown in Fig. 9. In this embodiment, however, the minimizing computing device 34 for directly minimizing power consumption differs from the one in the embodiment in Fig. 9 in the following respects. Specifically, in order to minimize power consumption, instead of using the manipulated variables, such as the number of revolutions of the compressor 2, and the opening angles of the bypass expansion valve 9 and the outdoor expansion valve 8, the target value of the suction pressure of the compressor 2 is corrected by using an adder 54, then additionally, the target value of discharge temperature or degree of superheat of the compressor 2 is corrected by using an adder 55, and moreover, the discharge pressure of the compressor 2 is corrected by using an adder 56. In the embodiments in Figs. 9 and 12, three manipulated variables or target values are corrected, but if the correcting method is complex, the search procedure may be simplified without correcting the outdoor expansion valve 8, for example, without departing from the subject-matter of the present invention.

In the above embodiments and modifications, arithmetic operations and control are performed by a digital computer. In this case, data necessary for control and arithmetic operations should preferably be

stored in memory means of the digital computer in table form shown in Fig. 13. By this arrangement, data can be referenced easily, and even if any problem arises, the problem can be dealt with readily.

Modified embodiments existing within the true spirit and scope of the present invention are all covered by the appended claims.

As has been described, according to the present invention, in addition to the conventional control function of maintaining the compressor in stable and safe condition and outputting the air conditioning capacity corresponding to the air conditioning load of each room, there is provided a function to retain the operating condition that power consumption is minimized. Therefore, power consumption which has been evaluated directly or by estimation can be reduced directly, and the present invention holds good promises for notable energy-saving effects.

CLAIMS

1. An air conditioning apparatus comprising an outdoor unit and at least one indoor unit connected by piping, and control means, said outdoor unit having a variable-revolution-speed compressor, an outdoor heat exchanger and an outdoor expansion valve sequentially connected by piping, said at least one indoor unit including an indoor heat exchanger, said control means being used for performing feedback control of controlled variables by using manipulated variables, wherein for said control means, electric power detecting means for detecting the electric power consumed by the air conditioning system is installed to enable said control means to perform feedback control including control to minimize said power consumption when deviations of the room temperatures or the air conditioning capacities from the target values are within specified ranges.

2. An air conditioning system according to Claim 1, wherein each said indoor unit includes an indoor expansion valve, and said control means controls opening angles of said indoor expansion valves.

3. An air conditioning system has an outdoor unit and a plurality of indoor units connected by piping, said outdoor unit having a variable-revolution-speed compressor, an outdoor heat exchanger and an outdoor expansion valve sequentially connected by piping, said plurality of indoor units each having an indoor heat exchanger and an indoor expansion valve connected by

piping, said air conditioning system comprising electric power detecting means for detecting power consumption of said air conditioning system, compressor temperature detecting means for detecting a discharge temperature of said compressor, room temperature detecting means for detecting temperatures of air flowing into said indoor heat exchangers, and control means for controlling the number of revolutions of said compressor and opening angles of said outdoor expansion valve and said indoor expansion valves, wherein said control means includes a first control portion for controlling a discharge pressure so as to approach a target value, a second control portion for controlling a discharge temperature of said compressor so as to approach a target value, and a third control portion for controlling said room temperatures so as to approach target values, and wherein for said control means, an electric power control portion is installed for receiving an electric power value detected by said electric power detecting means and outputting correction signals to said first to third control portions.

4. An air conditioning system according to Claim 2, wherein said control means includes a first feedback control portion for controlling a discharge pressure so as to approach a target value, a second feedback control portion for controlling a discharge temperature of said compressor and a third feedback control portion for controlling room temperatures so as to approach target

values, and wherein in said control means, an electric control portion is installed for receiving an electric power value detected by said electric power detecting means and outputting correction signals into feedback loops of said first to third feedback control portions.

5. An air conditioning system according to Claim 3 or 4, wherein detecting means for detecting a suction pressure is installed at said compressor, a fourth feedback control portion for controlling said suction pressure so as to approach the target value is installed in said control means, and said electric power control portion outputs a correction signal into said fourth feedback loop.

6. An air conditioning system according to Claim 2, wherein said control means includes a first feedback control portion for controlling a discharge pressure so as to approach a target value, a second feedback control portion for controlling a discharge temperature of said compressor, and a third feedback control portion for controlling room temperatures so as to approach target values, and wherein said control means further includes an electric power control portion for receiving an electric power value detected by said electric power detecting means, outputting correction signals through adders to feedback loops of said first and second feedback control portions, and also outputting a correction signal into a feedback loop of said third feedback control portion.

7. An air conditioning system according to Claim 6, wherein detecting means for detecting a suction pressure is installed at said compressor, a fourth feedback control portion for controlling said suction pressure so as to approach the target value is installed in said control means, and said electric power control portion outputs a correction signal through an adder into said fourth feedback loop.

8. An air conditioning system according to Claim 1 or 2, further comprising discharge pressure detecting means for detecting a discharge pressure of said compressor, temperature detecting means for detecting a discharge gas temperature or degree of superheat, electric power detecting means for detecting power consumption or current and voltage, room temperature detecting means for detecting temperatures of air flowing into said indoor units, setting means for setting set values of room temperature or target values of the air conditioning capacities of said indoor units, means for deciding a target value of the discharge pressure of said compressor, number of revolutions computing means for computing the number of revolutions of said compressor to reduce the deviation of the discharge pressure detected by the discharge pressure detecting means from the target value thereof, number of revolutions control means for controlling the number of compressor revolutions based on the result of the computation, means for deciding the target value of the discharge gas

temperature or the degree of superheat of the compressor, opening angle computing means for computing the opening angle of the outdoor expansion valve to reduce the deviation of the discharge gas temperature or the degree of superheat from the target value thereof, opening angle control means for controlling the opening angle of the outdoor expansion valve based on the result of the computation, and a control apparatus for, in order to further reduce power consumption of the multi-room air conditioning system detected by the electric power detector, putting deviations of the room temperature setting values or of the air conditioning capacities of said indoor units in operation from the target values in specified ranges and putting a deviation of the compressor discharge pressure from the target value and a deviation of the discharge gas temperature or the degree of superheat from the target value in specified ranges, and executing at least either the correction of the number of compressor revolutions and the correction of the outdoor expansion valve opening angle, or the correction of the target value of the compressor discharge pressure and the correction of the target value of the discharge gas temperature or the degree of superheat.

9. A method for operating an air conditioning system for providing comfortable air-conditioned spaces by feedback control, the air conditioning system having an outdoor unit and at least one indoor unit connected by

piping, said outdoor unit having a variable-revolution-speed compressor, an outdoor heat exchanger and an outdoor expansion valve sequentially connected by piping, and the at least one indoor unit having an indoor heat exchanger and an indoor expansion valve connected by piping, said method for operating the air conditioning system comprising the steps of:

after an optimum air-conditioned space is obtained by feedback control using the discharge pressure and temperature of the compressor and the temperatures of air flowing into the indoor units, correcting at least either the number of compressor revolutions or the opening angle of the outdoor expansion valve;

adjusting the opening angles of the indoor expansion valves so that the room temperatures of said indoor unit in operation are in a specified range when the detected value of the compressor discharge pressure or discharge temperature is in a specified range;

comparing the power consumption of an air conditioning system with the power consumption before the correction mentioned above; and

repeating the above procedure until the power consumption becomes minimum.

10. An air conditioning system according to any of Claims 3 to 8, wherein said first, second and third control portions each use a digital computer.

11. An air conditioning system according to any of Claims 3 to 8, wherein said control means includes

notifying means to give notice that power consumption has reached the minimum value.

12. An air conditioning system according to any of Claims 3 to 8, wherein said control means includes selection means for making a choice whether to execute control by said third control portion with regard to power consumption.

13. An air conditioning system substantially as herein described with reference to and as illustrated in Figs. 1,2, 4, 5 and 6, or Fig. 3, or Figs. 7 and 8, or Figs. 9, 10 and 11, or Fig. 12 of the accompanying drawings.

14. A method of operating an air conditioning system substantially as any one herein described with reference to and as illustrated in the accompanying drawings.

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Patents Act 1977
Examiner's report to the Comptroller under Section 17
(The Search report)

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Databases (see below)
(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii) ONLINE DATABASES: WPI

Search Examiner
MR G WERRETT

Date of completion of Search
28 JUNE 1995

Documents considered relevant following a search in respect of Claims :-
1 TO 14

Categories of documents

X: Document indicating lack of novelty or of inventive step.

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Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 2161298 A	(TOSHIBA) see current detector 30, Figures 7 and 8	1, 3, 9
X	GB 2152246 A	(MATSUSHITA) whole document	1, 3, 9

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